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Abstract

The preliminary purpose of this research on educational planning was to develop the methodology for the construction and to determine the feasibility of a computerized mathematical model that would project college and university enrollments in New York State. It was recommended that a simulation model be constructed as a prototype for a comprehensive state-wide model. The major thrust of this study was towards the development of such a model, to provide insights into its operating characteristics, and to evaluate its relationship to an information system for higher education in New York State. Section I describes the structure of the prototype simulation model --developed in the form of a working computer program-- from the standpoint of both the mathematics and the computer programing involved. Case studies were conducted at the City University of New York, Rensselaer Polytechnic Institute, and the Hudson Valley Community College in order to implement the model in 3 different yet collectively representative educational systems. Section II details the data requirements of the prototype model so that data collection problems discussed in the 3 case studies may be put into proper perspective. Section III reports on the case studies, which were designed to assess the facility of --and to reveal potential problem areas in -- the implementation of a full-scale model. Based on the results of the case studies, Section IV presents a set of conclusions and recommendations for additional work toward full-scale implementation of the model. (WM)

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CONSTRUCTION AND ANALYSIS OF
A PROTOTYPE PLANNING SIMULATION
FOR PROJECTING COLLEGE ENROLLMENTS

Rensselaer Research Corporation
Troy, New York
February, 1969

This report was prepared for the Office of Planning in Higher Education, State Education Department, University of the State of New York.

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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SECTION I

INTRODUCTION

A. The Plan of the Report

The major emphasis of the second phase of the research was two pronged: on the one hand, a prototype simulation model for planning in higher education was developed in the form of a working computer program; and on the other, three case studies were performed in order to evaluate some of the difficulties associated with the initialization and implementation of such a model.

Consequently, following this introductory section, the report concerns itself basically with the structure of the model from the standpoint of both the mathematics and the computer programming involved. This structure, as will be seen, has changed over time to a certain extent; these changes are outlined following the mathematical derivation. In order to clarify some of the capabilities of the model under consideration, an example of output from an actual computer run has been included. This output indicates the form and information content that can be expected, and shows how a "what if?" type question can be implemented. Finally in Section II have been included the details of the data requirements of the model so that the problems of data collection discussed in the cases can be put into proper perspective.

Section III of this report discusses three experiments designed to illuminate potential problem areas in the implementation of a full scale model. As experiments, these cases should be viewed as independent efforts directed toward the assessment of the facility with which a full scale model might be implemented in a real world context, rather than as actual attempts to implement the prototype.

Based upon the results of the above experiments, the final section deals with a set of conclusions and recommendations for further work toward the full scale implementation of a planning simulation model.

B. Background

In the summer of 1967, the Office of Planning in Higher Education of the New York State Department of Education contracted with Rensselaer Research Corporation to develop a conceptual model for the projection of enrollments in the college and university system of the State, and to determine the feasibility of construction of such a model in computerized form.[1] The results of this study being highly promising, a second contractual agreement was developed calling for:

1. programming of a prototype model for projecting enrollments;
2. evaluation of state and institutional data bases as they relate to implementation of a projection model;

3. collection of data at a few "representative" schools so that direction could be given to future data base content and collection methodology changes; and
4. use of this data with the prototype model so that its efficacy as a projection device could be evaluated.

As the research progressed, it became apparent that the needs of the educational planners could be better served if the capabilities of the prototype model were enlarged to show how experimentation with the values of model parameters for determination of their impact on projected enrollments could be accomplished. Thus the major thrust of the research has been redirected toward study of an enrollment projection and simulation model. Simulation shall be defined in the present context as "the dynamic representation of processes and events concomitant to the movement of students through the structural components of an educational system whose functional interrelationships are known or postulated and arranged in the representation to correspond to their assumed arrangement in the educational system." By this definition, the changing of parameter values in the model should give insights into the effects on the actual system of such changes.

Until the time of a redirection of the research activities, it was assumed that the model would be a planning aid because of the projections it would develop - these projections to be used as a basis for such considerations as budgetary, facilities, and manpower decisions. It is, however, now recognized that the student flow depicting structure of the model offers much more for analytic purposes than projected aggregate enrollments. Familiarization with this structure, originally chosen because of its completeness of description, can give educational planners the ability to comprehend the educational system as such, albeit in a simplified way. This comprehension will open new avenues of analytic thought and direction for planning analysis.

C. The Potential Role of Simulation in Educational Planning

The unique role that a simulation model can play in planning for a system of higher education is evident upon examination of the planning function in educational administration today. A highly specialized society demands that higher education be made available to increasing numbers of people from increasingly diverse backgrounds. Ever greater enrollment demands are being made on colleges and universities. College enrollments, composed of many groupings of people, are dependent in good measure on the exogeneous variables affecting these groups. Such factors as the Selective Service system, financial incentives, and federal policies have great influence on not only the academic community as a whole but on individual schools. While the planner must work from a base of steady-state enrollment projections, it is becoming even more important that we have a way of estimating reactions of these projections to possible external forces.

In addition, the need of educational planners for enrollment projections must be balanced between the desire for a meaningful and comprehensive format, and the need for enrollment projections in a more disaggregate and operational format. Those interested in the educational system's future faculty, facility, and budgetary needs are not greatly aided by a single projection of the total number of students in the educational system at some future date. More immediate questions are "will more students be attending two-year colleges? Will the proportions of students allocated to each curriculum be the same? Will my sector (public or private) gain in enrollment proportionately with present enrollments?" The prerequisite to use of a model which will aid in answering these questions is the input of data whose disaggregation and information content are commensurate with desired outputs.

The four techniques currently utilized in developing enrollment projections are cohort survival, ratio method, curve-fitting, and Markov analysis. In essence, the first technique develops retention proportions at successive levels of academic attainment (or grades) for groups of students (student cohorts) from past data. These retention proportions are then applied to present day first, second, and third grade students and to all other grades through twelve. Thus this year's high school seniors are the basis for next year's college freshmen; this year's high school juniors are the basis for projection of college freshmen "year after next," and so on. The ultimate result is a time-series of numbers of students in each grade for a number of years.

The ratio method is based on the assumption that a single age group comprising the bulk of the college-going population contains a fixed percentage of this population for each subsystem of the national educational system, for example, given a national projection of enrollment as well as total population in the nationwide 18-21 year old age group, this ratio may be applied to the State projection of the size of its 18-21 year old population resulting in an estimate of Statewide enrollment.

Curve-fitting is a more general technique than either the cohort survival or ratio methods. Any curve may be "fitted" with an equation. The use of the technique in enrollment projections is highly flexible and may be used to project any subgroup of the student population whose numbers are known for a past series of time periods and have a quantifiable relationship with some other variables.

The above three techniques as generally used do not give the analyst in higher education a complete and detailed picture of the movement or flow of students within the educational system as delimited by a detailed classification scheme involving levels, curricula, and/or institutions (See Figure 8 page for an example). As a result of this deficiency, the analyst is in a position to discuss the "how many" of future enrollments, but not the "how" or "why." As will be seen, the student flow approach combined with the concept of simulation yields a model which can accept "what-if" questions in terms of "how," "why," and "how many."

Since a simulation model can be made to react to the planners' "what-if" questions and can lead them to ask better ones, it enables them to assess their systems quantitative reactions to proposed policy changes. Although projections thus determined are to be thought of as answers to questions, implications drawn from qualitative observation of these figures enable the planner to be successively more specific in testing the system and his judgment; for example, the specification of the student flow process aids decision-making with regard to facilities location and curriculum development, while providing planners with information on the behavioral (or probabilistic) aspects of student flows through the educational system. The latter type of knowledge could then be recycled for use in the development of relationships between student flows and occurrences within or outside the system itself — occurrences whose effects would then be imposed on the simulated system for analysis of their impacts.

The conceptual scheme of the simulation constructed is suitable for application to various educational systems so long as they are well defined. The model, then, can simulate a state system, a single university, a college or school within that university, or even a department within a college. When the Statewide simulation is fully implemented, its usefulness will be determined in part by the input from individual institutions to the State. Ideally, this information will be taken from within the framework of a standard data reporting system. When such a system is implemented, the actual computer model in use by the State offices would in turn be directly useful to any institution within the State. Thus, the model must be flexible, so that it may be employed in planning throughout the segments of the total educational system.

Although the information system required for realization of the full potentiality of the model as an enrollment predictor is not in full operation, the prototype simulation model can provide additional understanding of the sensitivity of enrollments to changes in the educational environment. This information gives planners increased knowledge of the consequences associated with policy changes. Therefore, the prototype model has immediate utility and will increase in value as a planning tool with the development of a higher education information system.

D. A Brief Overview of Other Enrollment Projection and Educational System Simulation Models

The Markov type models being applied to educational planning can conveniently be classified by their scope, and the time-associated nature of their transition matrices. As regards scope, they are applied either to a single institution, or to some national educational system; and the transition elements are either constant or variable with time. In addition, the enrollment-associated aspects of educational planning may be approached basically in one of two ways: planning for demand, and planning for manpower requirements. Analytically, the latter is the more difficult in that given the future profile of the student constituents of the system under consideration, the analyst must solve for the time-path of profiles leading to the required one; in the case of planning for demand, no such solution is necessary.

Combining the model classifications with the two modes of approach yields a simple framework for the discussion of the models found in the literature to date. The most straightforward is DYNAMOD II. Developed for demand planning, it models the U.S. educational system with constant transition matrices. The human constituents of the system are classified for intra-system migration (flow) purposes as elementary, secondary, and college level students and teachers, and others. The model's fidelity may prove limited by transition matrix stationarity, and, for the higher educational planner, the need to spend time and effort on the projection of elementary and secondary enrollments. Preliminary results have been impressive and certainly useful, and work is being conducted toward developing sophisticated versions.

The models of Thonstad[3] were developed as aids to planning for manpower requirements, and they, too, utilize constant transition matrices. Like DYNAMOD II, they are large-scale in that they represent a national educational system. Thonstad applies some of the formal results of stationary Markov chains to gain insight into the long-run implications of the present student flows in Norway, and although he states the required assumptions clearly, the justification of his application remains to be seen as the assumptions do not logically hold true (e.g., students have no memory).

The models of Gani, and Koenig, et.al., developed for demand planning, are smaller in scope, representing only the single institution of higher learning. Neither assumes stationary transition matrices, although Gani's most recent work attributes a periodicity to them. Neither model distinguishes, as yet, between the different curriculum-switching characteristics of different types of students (male versus female, etc.).

A comprehensive review of the relevant literature indicates that only a small number of enrollment projection models have been developed for experimental purposes, one being DYNAMOD II, whose simulative capabilities are not as comprehensive as the one under consideration in this report.

The consulting firm of Peat, Marwick and Livingston, and the research team of R. W. Judy and J. B. Levine at the University of Toronto have constructed computer simulation models of educational systems, although they are not strictly comparable to the present work. Using a modified cohort survival approach in the case of the former, and exogenous input of projected enrollments in the case of the latter, the models simulate the future states of such system components as faculty, library, budget, and facilities based on the policy decisions made by the analyst in simulated "present time." While such computations are a highly useful portion of any educational system simulation in that they show the interrelationships between additional components of the system and assign them dollar values, the planner must still contend with the "how" and "why" of enrollments and the accuracy of enrollment projections.

Therefore, the most comprehensive and beneficial simulation model under consideration with the type of model which transforms enrollments into facilities, faculty, library, and dollar requirements.

E. The Project as a Learning Process

It should be stressed that the research and development reported in this work involved a continuing learning process on the part of all involved. Although the basic concept of the model as earlier conceived remains unchanged, it must be noted that the model developed was a prototype — and as such, subject to change as experience with it was amassed. As will be seen, the "case study" applications of the model required different forms of input and output data, implying change in the structure itself. While structural changes have been made, they have been made purely as a function of the desires of its potential users.

It is to be expected that additional changes in the model will be made as educational planners gain experience with it, and as their needs and those of the educational system undergo change and development. Unless the use of *any* model is accompanied by a constant monitoring and continuing efforts to improve it, model usage may be more damaging than constructive: measures of confidence in model results will be unfounded, and may lead to the choice of impractical alternatives as courses of action. The importance of this statement cannot be overemphasized.

SECTION II

A SIMULATION MODEL OF AN EDUCATIONAL ENVIRONMENT

A. A General Overview

1. Definitions

Before discussion of the mathematics of the model, it would be efficacious to define some of the terms to be used.

The basic structural delimiter of the educational system as represented by the simulation model is called the major classification scheme. As used henceforth, a major classification scheme refers to some combination of certain structural components of an educational system: levels, such as freshman, sophomore, junior, senior, and graduate, or upper and lower divisions; colleges or college types, such as two or four year, public or private, large and small; or curricula such as science, non-science, or architecture, engineering, humanities, business, and science. Thus while one analyst may be interested in a model depicting the educational system as a series of levels, another may have specific interest in university control and the science-non-science curricula to the exclusion of academic level, while a third's interests may lie with analysis of the single institution as a series of levels each having a set of major fields.

The foregoing definitions will be clarified in the material to follow. It is suggested that the reader refer to Figures 2, 11, 17 and 18 on pages 21, 121, 150, and 158, respectively, for examples of the concept of major classification scheme and its application.

In an educational system, students move from lower to higher levels as they fulfill the academic requirements of the former; they move among the curricula within a single institution, and among institutions. Thus a student might move from the sophomore level of science at college A to the junior level in humanities at college B. In the aggregate, these movements of students may be viewed as "flows" through an educational system, whether that system be delimited in terms of levels, curricula, college types, colleges, or some combination of them. (Diagrammatic examples of student flows can be found in Figures 14 and 15 on pages 129 and 130 respectively while further discussion of this concept may be found in The Development of a Computer Model for Projecting Statewide College Enrollment: A Preliminary Study.)

A compact representation of these student flows is offered through the use of matrices of percentages representing the frequency or probability with which students move among system components as delimited by the major classification scheme. Such a matrix may be termed a transition matrix, and the movements or flows transitions. To clarify the notion of movements between the components of an education system, the matrix on the following page (Figure 1) represents the flows between the components of one possible major classification scheme. Here the major classification scheme has six components: two divisions, two curricula, and two types of school. Although in general it would be expected that the number of components would equal the product of the numbers associated with the levels, curricula, colleges and college types, (2x2x2=8), the case presented is an exception since there is no upper division, as tacitly defined, in two year schools: lower division includes only first and second year students, while upper division also includes third, fourth, and graduate students, none of whom exist in two-year schools. Again, these definitions are germane only to the example at hand, and are completely a function of the system or subsystem of interest.

Following conventional subscripting notation in Figure 1, the value in the ith row and jth column of the transition matrix, a_{ij}, represents the proportion of students in major classification i who, between two successive time periods, make a transition to major classification j. Thus in our example, a_{45} would be the proportion of lower division non-science students in four year schools who, for the following period, became upper division science majors in four year

STUDENTS' LOCATIONS AT TIME t			STUDENTS' LOCATIONS AT TIME t+1					
			LOWER DIVISION				UPPER DIVISION	
			2 Year		4 Year		4 Year	
			SCI	N-SCI	SCI	N-SCI	SCI	N-SCI
LOWER DIVISION	2 YEAR	SCIENCE	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}
		NON-SCIENCE	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}
	4 YEAR	SCIENCE	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}
		NON-SCIENCE	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}
UPPER DIVISION	4 YEAR	SCIENCE	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}
		NON-SCIENCE	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	a_{66}

FIGURE 1

EXAMPLE OF A TRANSITION MATRIX

KEY:
Major Classification Scheme Components:
  Lower Division 2 year science.
  Lower Division 2 year non-science.
  Lower Division 4 year science.
  Lower Division 4 year non-science
  Upper Division 4 year science.
  Upper Division 4 year non-science.
  Number of components = 6.
  Direction of flow: i to j for a_{ij}.

schools, as can be read from the row and column headings about the matrix of the figure.

Strictly speaking, the above matrix is not complete as it stands. The sum of the percentages across any row must be one hundred per cent, since all students who start in a classification must either stay in that classification or move somewhere. "Somewhere" might be either in the educational system or outside of it: thus the matrix must be augmented by at least one column representing "outside" the educational system as delineated by the major classification scheme. The latter single column might then be divided into "academic attrition," "mortality," and "graduated," thereby detailing the fate of those who leave the educational system. Having augmented the transition matrix such that the possible destinations of a group of students starting in a given classification form a collectively exhaustive set, the row sums of percentages will indeed equal one hundred per cent.

If the analyst has chosen the major classification scheme most suitable to his reference frame for analysis, it is expected that he would be interested not only in the flows between the components of the system as he has defined them, but in the numbers of students in each of the components at particular points in time. The latter numbers can be arranged in vector form as follows:

$$\begin{array}{cccccc} \multicolumn{4}{c}{\text{LOWER DIVISION}} & \multicolumn{2}{c}{\text{UPPER DIVISION}} \\ \multicolumn{2}{c}{\text{2 year}} & \multicolumn{2}{c}{\text{4 year}} & \multicolumn{2}{c}{\text{4 year}} \\ \text{Sci.} & \text{N-Sci.} & \text{Sci.} & \text{N-Sci.} & \text{Sci.} & \text{N-Sci.} \\ (\,n_1 & n_2 & n_3 & n_4 & n_5 & n_6\,) \end{array}$$

where n_j is the number of students in classification j, and the subscript corresponds to the major classification scheme used for delineation of the transition matrices as shown by the headings over the vector.

Associated with each of the groups of students n_j is a set of attributes which shall be termed student characteristics. These characteristics, corresponding to the informational needs of the planner, might be those of sex, age, geographic origin, economic status, marital status, or CEEB scores. Each characteristic would be divisible into two or more categories: for example, sex would be divided into the categories "male" and "female," while age could be divided into "under 17," "17-20," "21-25," and "26 or above." Moreover, additional information concerning the major classification scheme could be incorporated into the set of descriptive attributes (characteristics): for the scheme under consideration in the example, one such addition would be that of "level," where the categories under level would be "freshmen," "sophomore," and so forth. While flow information on these specific categories would not be available given the structure of the major classification scheme, the planner would have the additional knowledge of the projected breakdown by level of student in each of the divisional levels.

The number of characteristics, and the number of categories within each of the latter is bounded by both the size of the computing equipment being used and the availability of requisite data. The single requirement for the categories under a particular characteristic is that _they describe the characteristic exhaustively, and that they be mutually exclusive_. Thus, for example, the categories under the characteristic _age_, above, allowed for any age, and did not overlap.

Each group of students, n_1, n_2, n_3, n_4, n_5, and n_6 in our example, would be described by the same set of characteristics and categories. The vector of n's may thus be expanded into a matrix whose columns are associated with the major classification scheme, and each of whose rows corresponds to a single category of a characteristic. An example is pictured in Figure 2: the classification subscript on the n's has been proceeded by a category subscript. The total number of lower division, science students in two year schools n_1 (from the vector of students by major classification), has been divided into six categories. Obviously, every student has a gender and an age, and obviously, the number of students with a gender equals the number of students with an age equals the total number of students in that classification. Again following conventional

		LOWER DIVISION				UPPER DIVISION	
		2 Year		4 Year		4 Year	
		SCI	N-SCI	SCI	N-SCI	SCI	N-SCI
SEX	MALE	n_{11}	n_{12}	n_{12}	n_{14}	n_{15}	n_{16}
	FEMALE	n_{21}	n_{22}	n_{23}	n_{24}	n_{25}	n_{26}
AGE	UNDER 17	n_{31}	n_{32}	n_{33}	n_{34}	n_{35}	n_{36}
	17-20	n_{41}	n_{42}	n_{43}	n_{44}	n_{45}	n_{46}
	21-25	n_{51}	n_{52}	n_{53}	n_{54}	n_{55}	n_{56}
	26 AND UP	n_{61}	n_{62}	n_{63}	n_{64}	n_{65}	n_{66}

FIGURE 2

MATRIX OF STUDENTS BY CLASSIFICATION & CATEGORIES OF CHARACTERISTICS

KEY:
- Characteristics:
  - Sex
  - Age
- Categories of Sex:
  - Male
  - Female
- Total categories of characteristics = 6.
- Categories of Age
  - Under 17
  - 17-20
  - 21-25
  - 26 and up

subscripting notation with the first subscript denoting "row" and the second "column," $n_{1j} + n_{2j}$ equals $n_{3j} + n_{4j} + n_{5j} + n_{6j}$ for any j.

2. Aging and Projection

In essence, the matrix of total students grouped by classification and category of characteristic for one period is multiplied by the transition matrix for that period which results in the matrix of those students remaining in the educational system, by classification and category of characteristic, for the next period. To the latter matrix are added two similarly classified and categorized matrices: one of first-time freshman entrants into the educational system; the other of upper-level entrants into the educational system. The sum of the three matrices is a new matrix of total students by classification and category of characteristic for this next period. Performing this process repeatedly, the outcome is a time-associated series of matrices of numbers of students by the major classification scheme and categories of characteristics. In this way, successive classes of students are "aged" through the educational system, ultimately leaving it either with (or without) one or more degrees. Although the fact has not yet been made explicit, there are three types of "characteristics" which can be used to describe students. Some are "fixed;" such as sex; some are "irregularly variable" such as status (full or part-time); some are "regularly variable" such as age. Only the first and third types may be validly cycled through a transition matrix. The irregularly variable characteristics are actually associated with student flows and are accounted for, if not in the major classification scheme, by separate projection of percentages in each category of the given characteristic, over all components in the major classification scheme.

Before this aging process can begin, the model must first project the time series of transition matrices and the matrices of entering students (first-time freshmen and upper-level entrants) for the years succeeding those for which historical data are available. Since the projection methodology will be discussed in detail in a later section great detail is not presented here, although a general view of the projection method follows.

It is the historical data upon which the projections are based. The vehicle for the projections is linear regression.* As applied in the model under discussion, the technique fits a curve to the time ordered values of the historical data; the closeness of fit is a function of the time-ordered values of another set of (independent) variables felt to be relevant to the former (dependent) variables. The equation of the resultant curve, expressing the value of the dependent variable as a function of any set of values of the independent variables, would then yield projections of the value of the dependent variable for future sets of values of the independent variables.

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*"The term linear regression implies linearity in the parameters of the regression, but does not necessarily denote 'a straight line'".

As the relationship (not necessarily causal) between a given pair of dependent and independent variables becomes more pronounced, the calculated equation fits the actual data more closely: in addition, a closer "fit" is obtained as the number of independent variables is increased, although the significance of the regression may not increase meaningfully. However, the number of independent variables is limited by the amount of historical data upon which the projections are to be based, more specifically, by the number of observations on each datum. While there may be as many independent variables as there are observations, typically the number of such variables are kept much smaller than the number of observations so that statistical confidence limits may be attached to the coefficients of the predictive regression equation.

Each element in each matrix is taken as a dependent variable, so that projection of a matrix actually reduces to the projection of each of its separate elements. Moreover, the three matrices to be projected are treated as separate projection problems to allow the flexibility for change to potentially more accurate methods of projection for the different quantities. A simple example of this flexibility would be that of using different sets of independent variables for projection of the three different sets of matrices used by the model.

3. Dynamic and Episodic Updating

After projection of matrices and aging of successive classes of students have been accomplished, the model user may develop a new set of projections based on a different set of assumptions from those of the first run. More specifically he may, for any projected year, change the calculated transition proportions and/or the calculated numbers of first-time freshmen or upper-level entrants. Here the user is asking, in essence, "what impact on future enrollments will event 'X' have, if its initial effect is 'Y'?" The model is constructed such that all projected values for simulated years subsequent to that in which the changes have been instituted are updated as a function of the changes.

Changed projections imposed by the user are incorporated into the subsequent projections in one of two ways. The planner may have the changed variable values utilized in the curve-fitting process as pseudo-historical data, thereby changing the calculated trends of those variables; or he may alternatively incorporate the changed values as a one-time affair or "episodic event" whose effects will decrease over time and eventually die out with no change in calculated trends. The updating of the original projections which takes place with each of these approaches is called a "dynamic update" or an "episodic update," respectively.

It is important to note that two separate runs based on changed assumptions regarding the same projected year will give results as if all assumptions had been incorporated in the same run. Thus if a given run's assumptions are incorporated as new "trend data" (a dynamic update) in transition matrices, and the subsequent run's assumptions are incorporated as episodic events affecting numbers of entering freshmen, the result of the latter run will contain the revised trend data of the transition elements. Both episodic and dynamic updating will be discussed in more detail in the following section. While the following delineation provides an analysis of the structure of the model as a system of mathematical constructs, understanding of this medium of presentation is by no means a prerequisite to fully comprehend the logical framework of the simulation.

B. The Mathematical Model

1. The Aging Process

Using the terms defined in A.1 of this Section, let

n_{ijk} represent the number of students with characteristic i in classification j at the start of academic period k;

a_{pjk} represent the percentage of students who, during period k, transferred from classification p to classification j so that at the start of period k+1, they entered classification j;

t_{ijk} represent the number of first-time freshmen with characteristic i in classification j at the start of academic period k;

e_{ijk} represent the number of students with characteristic i who enter classification j of the educational system in period k other than first-time freshmen.

If we define v_{ijk} as the number of students with characteristic i in classification j at the start of period k excluding those that entered the educational system at the start of or during period k, then

$$n_{ijk} = v_{ijk} + t_{ijk} + e_{ijk} \tag{1}$$

Assume a total of I categories of characteristics, with c_r representing the number of categories under the rth characteristic. Then if N is the number of characteristics,

$$c_1 + c_2 + \ldots + c_N = I. \qquad (2)$$

Since the categories under each characteristic are mutually exclusive and collectively exhaustive (in terms of each characteristic), the number of students with one characteristic must equal the number with any other characteristic as we have defined the latter term. Thus

$$\sum_{i=1}^{c_1} n_{ijk} = \sum_{c_1+1}^{c_1+c_2} n_{ijk} = \ldots = \sum_{I-c_r+1}^{I} n_{ijk} = n_{.jk}, \qquad (3)$$

where the dot indicates a sum over all relevant values of the replaced subscript and each of the equated expressions equals the total number of students in classification j at the start of period k. It might be noted that the model, as programmed, uses the first sum in the series (3) for determination of this total number of students.

Since both first-time freshman and upper-level entrants to the educational system are classified and categorized in exactly the same way as are the groups of total students, it is apparent that the number of first-time freshmen in classification j at the start of period k is

$$t_{.jk} = \sum_{i=1}^{c_1} t_{ijk} \qquad (4)$$

and similarly that the number of upper-level entrants into classification j in period k is

$$e_{.jk} = \sum_{i=1}^{c_1} e_{ijk}. \tag{5}$$

Summing over any single characteristic in equation (1) therefore yields

$$n_{.jk} = v_{.jk} + t_{.jk} + e_{.jk}. \tag{6}$$

At this point, note must be taken of an assumption inherent in the present running program of the model and, as will be seen, in the equations to follow. As a first approximation, it has been assumed that transition probabilities or frequencies are independent of students' personal characteristics. Thus, for example, sex has no bearing on inter-curricular or inter-collegiate transitions. Obviously, such is not the case in an actual educational system, and a measure of the potential fidelity of the model is lost. As the refinement and scope of educational data collection systems increase, a relatively simple reprogramming of the model coupled with input of more refined data will allow relaxation of this assumption. The mathematical relations of the more general case — that is, dependence between characteristics and transition probabilities, will be shown subsequently.

Since as a first approximation we have made the assumption that the characteristics describing students have no bearing on the students' transition probabilities, we may write

$$v_{11(k+1)} = n_{11k}a_{11k}+n_{12k}a_{21k} + \dots + n_{IJk}a_{JIk}, \qquad (7.a)$$

where J is the total number of classifications in the major classification scheme chosen. In words, (7.a) states that the number of students in personal characteristics category 1 and major classification 1 at the start of period k+1 who were in the educational system in the previous period (k) is equal to the sum of the numbers of students with that category (1) of personal characteristic who transferred to classification 1 from all classifications (including classification 1) at the end of period k. In view of our aforementioned assumption, we may write for the second characteristics category

$$v_{21(k+1)} = n_{21k}a_{11k}+n_{22k}a_{21k} + \dots + n_{2Jk}a_{J1k} \qquad (7.b)$$

$$\vdots$$

$$v_{I1(k+1)} = n_{I1k}a_{11k}+n_{I2k}a_{21k} + \dots + n_{IJk}a_{J1k}. \qquad (7.c)$$

The subscripts of the a's in (7.a) through (7.c) are, of course, the same, indicating that the proportion of students moving from a given classification to classification 1 is the same regardless of which of the I categories of characteristics is possessed by each group of students. Thus, for example, the percentage of males moving from "A" to "B" is the same as the percentage of females doing so. From equations (7) it is seen that for the ith category of characteristics, the number of classification 1 students at the start of period k+1 who were in the educational system at time k is

$$v_{i1(k+1)} = n_{i1k}a_{11k} + n_{i2k}a_{21k} + \ldots + n_{iJk}a_{J1k}. \tag{8}$$

By analogy, the number of classification j students at the start of period k+1 who were in the educational system at time k is, for any category of characteristic i:

$$v_{ij(k+1)} = n_{i1k}a_{ijk} + n_{i2k}a_{2jk} + \ldots + n_{iJk}a_{Jjk}. \tag{9}$$

Equations (7) are one of J subsets of the equations represented by the expression in (9): in the former, j is held equal to 1, while in the latter, the more general expression, each of the J subsets contains I equations. Recalling equation (2) and the fact that the categories under a given characteristic are collectively exhaustive, then for any classification j,

$$v_{1j(k+1)} = \sum_{i=1}^{c_1} v_{ij(k+1)}, \tag{10}$$

and, summing now down the columns of the right-hand side of equations (9) with j constant gives the expression

$$a_{ijk} \sum_{i=1}^{c_1} n_{i1k} + a_{2jk} \sum_{i=1}^{c_1} n_{i2k} + \ldots + a_{Jjk} \sum_{i=1}^{c_1} n_{iJk}, \tag{11.a}$$

which from (3) may be rewritten

$$a_{ijk}n_{.1k} + a_{2jk}n_{.2k} + \ldots + a_{Jjk}n_{.Jk}. \tag{11.b}$$

Accordingly,

$$v_{.j(k+1)} = \sum_{s=1}^{J} a_{sjk} n_{.sk}, \tag{12}$$

and substitution of (12) into (6) finally yields

$$n_{.j(k+1)} = \sum_{s=1}^{J} a_{sjk} n_{.sk} + t_{.j(k+1)} + e_{.j(k+1)}. \tag{13}$$

This recursive relationship succinctly indicates the essence of the aging process of the model. In words it states that the number of students in some classification or component of the educational system at the start of some time period is equal to the sum of the numbers of students in three main segments of the student population at the start of that period: those who were in the system in the previous period and have made a transition to the classification in question; those who enter the classification as first-time freshmen in the period under consideration, and those who enter the pertinent classification at other levels in that same time period.

As has been mentioned, the equations subsequent to (6) are not valid unless the assumption is made of independence between student characteristics and transition probabilities. Strictly speaking, relationship (13) should include reference to the fact that different characteristics may relate to differing transition probabilities. If it is postulated that the most general case would be one in which each category within each characteristic is associated with a different set of transition probabilities, then (13) may be generalized by introducing a superscript on the a_{sjk}. The superscript would, of course, range from 1 to I, indicating that a_{sjk} for one category may be different from a_{sjk} for another. Starting with equations (7.a)-(7.c) we have

$$v_{11(k+1)} = n_{11k}a^{(1)}_{11k}+n_{12k}a^{(1)}_{21k} + \dots + n_{1Jk}a^{(1)}_{J1k}, \qquad (14.a)$$

$$\vdots$$

$$v_{I1(k+1)} = n_{I1k}a^{(I)}_{11k}+n_{I2k}a^{(I)}_{21k} + \dots + n_{IJk}a^{(I)}_{J1k}. \qquad (14.c)$$

With equations (8) and (9) generalizing over category of characteristic and classification, respectively, (9) becomes

$$v_{ij(k+1)} = n_{i1k}a^{(i)}_{1jk}+n_{i2k}a^{(i)}_{2jk} + \dots + n_{iJk}a^{(i)}_{Jjk}. \qquad (15)$$

While equation (1) still holds, (11.a) is invalid since $a^{(i)}_{sjk}$ is no longer constant for $(i=1,2,\dots,c_1)$, and so forth. Thus the a's cannot be removed from within the summations as constants. When the columns of equations (15) are summed over some characteristic (we will continue to use the "first" with $i=1,2,3,\dots,c_1$) and the result of (10) is inserted, we have

$$v_{.1(k+1)} = \sum_{i=1}^{c_1} a^{(i)}_{1jk}n_{i1k} + \sum_{i=1}^{c_1} a^{(i)}_{2Jk}n_{i2k} + \dots + \sum_{i=1}^{c_1} a^{(i)}_{Jjk}n_{iJk} \qquad (16)$$

$$= \sum_{s=1}^{J} \sum_{i=1}^{c_1} a^{(i)}_{sjk}n_{isk}; \qquad (17)$$

and finally, substituting into (6),

$$n_{.j(k+1)} = \sum_{s=1}^{J} \sum_{i=1}^{c_1} a^{(i)}_{sjk} n_{isk} + t_{.j(k+1)} + e_{.j(k+1)}, \tag{18}$$

which reduces to (13) for $a^{(1)}_{sjk} = a^{(2)}_{sjk} = \dots = a^{(3)}_{sjk}$. It will facilitate future discussion if a matrix notation is introduced for compactness. Analogous with previous definitions, then, let

$$N_k = \begin{bmatrix} n_{11k} & n_{12k} & n_{13k} & \cdots & n_{1Jk} \\ n_{21k} & n_{22k} & n_{23k} & \cdots & n_{2Jk} \\ & \vdots & & & \\ n_{I1k} & n_{I2k} & n_{I3k} & \cdots & n_{IJk} \end{bmatrix}; \tag{19.a}$$

$$A_k = \begin{bmatrix} a_{11k} & a_{12k} & a_{13k} & \cdots & a_{1jk} \\ a_{21k} & a_{22k} & a_{23k} & \cdots & a_{2Jk} \\ & \vdots & & & \\ a_{J1k} & a_{J2k} & a_{J3k} & \cdots & a_{JJk} \end{bmatrix}; \tag{19.b}$$

$$T_k = \begin{bmatrix} t_{11k} & t_{12k} & t_{13k} & \cdots & t_{1Jk} \\ t_{21k} & t_{22k} & t_{23k} & \cdots & t_{2Jk} \\ & \vdots & & & \\ t_{I1k} & t_{I2k} & t_{I3k} & \cdots & t_{IJk} \end{bmatrix}; \tag{19.c}$$

$$E_k = \begin{bmatrix} e_{11k} & e_{12k} & e_{13k} & \cdots & e_{1Jk} \\ e_{21k} & e_{22k} & e_{23k} & \cdots & e_{2Jk} \\ & \vdots & & & \\ e_{I1k} & e_{I2k} & e_{I3k} & \cdots & e_{IJk} \end{bmatrix}; \tag{19.d}$$

and let $A_k^{(a)}$ represent the non-square matrix of transitions composed of A_k and additional augmenting columns showing the percentages of students leaving the educational system either through academic attrition, mortality, or completion of degree requirements.

Again reverting to the assumption that transition probabilities are independent of personal characteristics, equations (19) may be substituted into equations (13), thus expressing the recursive relationship more compactly as

$$N_{k+1} = N_k A_k + T_{k+1} + E_{k+1}. \tag{20}$$

2. The Projection Process

Multiple regression was chosen as the projection technique due to its flexibility in terms of the selection of independent variables upon which the projections are based. The number of independent variables upon which the regression is based may be as large as the number of distinct data points. We are, accordingly, afforded ample opportunity for combining independent variables assumed related to the dependent variables, and thus increasing the "goodness of fit" of the regression line although there is a corresponding loss of information as to the statistical confidence limits on the projections as the number of independent variables increases.

As used henceforth, "one observation" includes all data pertaining to a particular point or interval of time. Since the data for the model are presently being collected for a yearly basis, values of all variables for a given year would be included as part of the single observation for that year. Thus, for example, T_k, E_k, and $A_k^{(a)}$ are all included in the "single" observation on the dependent variables for year k.

If Y were a uX1 vector of observations on some dependent variable, X were a uXm matrix of observation on m independent variables, and $\hat{\beta}$ were the mX1 vector of regression coefficients which minimizes the sum of squares of the differences between the elements of Y and those of Y (the predicted value of Y based on β), then the normal equations

$$X'X\hat{\beta} = X'Y \tag{21}$$

(where the ' indicates transpose) would be solved for β as

$$\hat{\beta} = (X'X)^{-1}X'Y \tag{22}$$

with the (-1) superscript indicating the inverse of the matrix. A projection would be made, for a given set of values of the independent variables, as

$$Y = x\hat{\beta}, \tag{23}$$

where x represents the set of observations on the independent variables.

The expansion of the normal equations to include more than one set of dependent variables is straightforward:

if, in (21), Y were uX2, then with X unchanged, $\hat{\beta}$ would be mX2. The tacit assumption here is that the same regression model has been chosen to describe the relationship between the independent variables and each of the (2) dependent variables. The degree to which this assumption holds is a function of:

(1) the similarity of the natures of the dependent variables themselves, and

(2) the association to the dependent variables of the set of independent variables, one measure being their correlation.

As a first approximation, the same regression model for prediction of first-time freshmen regardless of curriculum or college has been assumed.

If Y were I$X\phi X$u, that is, if u observations were taken on a matrix with I rows and ϕ columns, $\hat{\beta}$ would be I$X\phi X$m (again assuming m independent variables). The normal equations, still unchanged in the matrix notation, would be the same regardless of the number of dimensions associated with Y. To exemplify the projection process for the matrices making up the main structure of the model, we detail the description of the projection of an augmented transition matrix: the latter is I$X\phi$, $\phi>I$, and although the matrices T_k and E_k are IXJ, all are two-dimensional for a given k so that the methodology for projection of $A_k^{(a)}$ holds for projection of T_k and E_k. As stated previously, however, the latter three quantities are taken to present three separate problems for projection, and they are treated as such. Thus while the X matrix (matrix of observations on the independent variable) may not vary for the projection of the different elements of T_k, it may vary between the latter and E_k or $A_k^{(a)}$.

Since $A_k^{(a)}$ is $I X \phi$ and we have assumed u observations on $A_k^{(a)}$, assume that the plane of the following page represents the first point in time at which complete data required by the model are available. Let an imaginary second plane, behind and parallel to the first represent the matrix observed at the second point in time for which complete data are available, and so forth. Then the historical data upon which the regression and projection are to be based is represented by u planes, the u^{th} representing the last or most recent year for which complete data are available. In essence, the time dimension is perpendicular to the paper in Figure 3, on the following page. With m independent variables upon which to regress the dependent variables, and u observations on each of the independent (as well as the dependent) variables, X takes the form in Figure 4, where at least one of the columns would represent the values of some function of time, and the "zeroth" column giving the opportunity for calculation of an intercept of the regression curve.

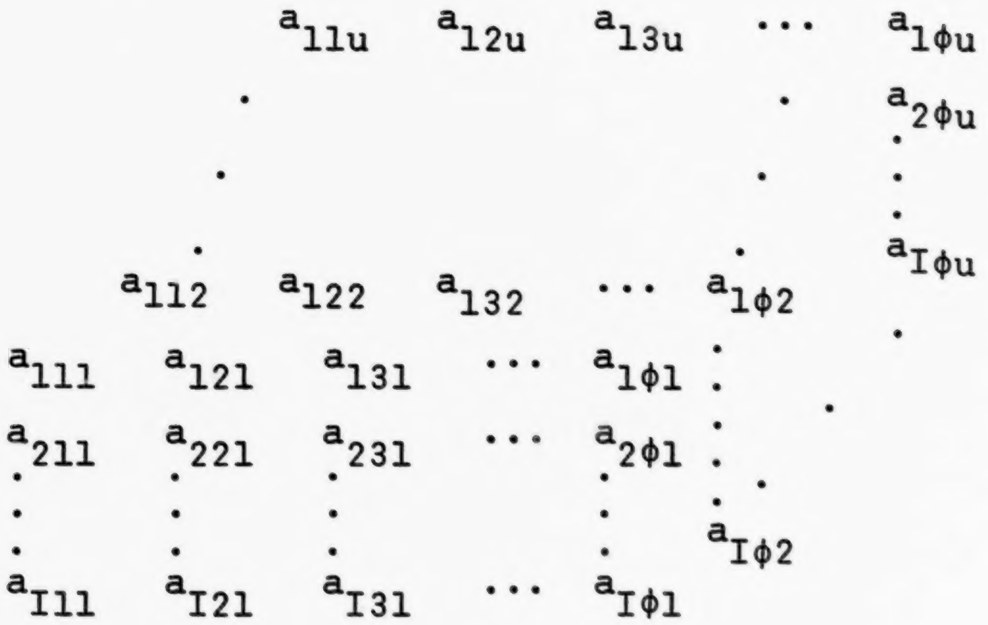
a_{11u} a_{12u} a_{13u} ... $a_{1\phi u}$
$a_{2\phi u}$
$a_{I\phi u}$
a_{112} a_{122} a_{132} ... $a_{1\phi 2}$
a_{111} a_{121} a_{131} ... $a_{1\phi 1}$
a_{211} a_{221} a_{231} ... $a_{2\phi 1}$
$a_{I\phi 2}$
a_{I11} a_{I21} a_{I31} ... $a_{I\phi 1}$

FIGURE 3

3 - DIMENSIONAL REPRESENTATION OF A TRANSITION MATRIX

$$X = \begin{bmatrix} x_{10} & x_{11} & x_{12} & \cdots & x_{1m} \\ x_{20} & x_{21} & x_{22} & \cdots & x_{2m} \\ x_{30} & x_{31} & x_{32} & \cdots & x_{3m} \\ \vdots & \vdots & \vdots & & \vdots \\ x_{u0} & x_{u1} & x_{u2} & \cdots & x_{um} \end{bmatrix} \qquad (24)$$

FIGURE 4

MATRIX OF OBSERVATIONS ON THE INDEPENDENT VARIABLES

Again, this matrix is the same for regression of any and all elements of $A_k^{(a)}$. Thus in the normal equations (21) and their solution (22), X is constant as is $(X'X)^{-1}X'$, hereafter denoted

$$C_a = (X'X)^{-1}X'. \qquad (25)$$

Taking the projection of the "upper left-hand" element of the transition matrix as a small regression problem in itself, regression coefficients can be found by solving

$$C_a \times \begin{bmatrix} a_{111} \\ a_{112} \\ a_{113} \\ \vdots \\ a_{11u} \end{bmatrix} = \hat{\beta}_{11}, \qquad (26)$$

where $\hat{\beta}_{11}$ is mX1 with elements

$$\begin{bmatrix} b_{011} \\ b_{111} \\ b_{211} \\ \cdot \\ \cdot \\ \cdot \\ b_{11} \end{bmatrix} \tag{27}$$

Similarly for the j^{th} element in the i^{th} row of $A_k^{(a)}$,

$$\hat{\beta}_{ij} = C_a \times \begin{bmatrix} a_{ij1} \\ a_{ij2} \\ a_{ij3} \\ \cdot \\ \cdot \\ \cdot \\ a_{iju} \end{bmatrix} = \begin{bmatrix} b_{0ij} \\ b_{1ij} \\ b_{2ij} \\ \cdot \\ \cdot \\ \cdot \\ b_{mij} \end{bmatrix} \tag{28}$$

Thus the calculation of regression coefficients for the transition matrix as a whole results in a three-dimensional array of coefficients — two of which correspond to the size of the matrix to be projected, and one of which corresponds to the number of independent variables (m) upon which the regression is based. An obvious notation to describe all calculations represented by (28) would be*

$$\hat{\beta}_a = C_a A^{(a)}, \tag{29}$$

where $\hat{\beta}_a$ is IXϕXm, and $A^{(a)}$ is the three-dimensional array of Figure 3. Analogously, the coefficients developed by regression of the observations on E_k and T_k are given by

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*It is recognized that as defined, C_a is not conformable with $A^{(a)}$ for multiplication. C_a would be (1xmxu) for conformability.

$$\hat{\beta}_e = C_e E \tag{30}$$

and

$$\hat{\beta}_t = C_t T,$$

respectively, where E and T would be the three dimensional representation, as in Figure 3, of the observations for $k = 1$ to u on E_k and T_k; $\hat{\beta}_e$ and $\hat{\beta}_t$ are the three-dimensional matrices of regression coefficients; and C_e and C_t are the constant terms $(X'X)^{-1}X'$ which, as will be recalled, may vary between $A^{(a)}$, T, and E.

Depending upon the judgment and experience of the model user, and the data available, C_t and C_e may or may not equal C_a. This implies that the independent variables used for projection of first-time freshmen, upper-level entrants, and transition probabilities may be based on different variables, or upon different functions of the same variables. To date, all runs with the model have been carried out with $C_a = C_t = C_e$.

Having calculated the matrices of regression coefficients, projected values of $A_k^{(a)}$, T_k and E_k $(k \times u)$ are obtained for sequential sets of values of the independent variables, essentially through the use of equation (23).

Expanding the notation on the vector of independent variable values used for projection of the dependent variables (the former is the vector "x" of equation (23)), let the first subscript (either a, e, or t) represent the set of independent variables with which the vector is associated, and the second represent the point in time with which the values of the vector are (assumed) associated. Thus, for example, $x_{a(u+p)}$ represents the 1xm vector of assumed values of the independent variables related to the transition elements at time u+p. The matrix equations for projection of $A^{(a)}_{k+p}$, T_{k+p}, and E_{k+p} are given by equations (31.a) through (31.c):

$$A_{k+p} = x_{a(k+p)}\hat{\beta}_a \; ; \tag{31.a}$$

$$T_{k+p} = x_{t(k+p)}\hat{\beta}_t \; ; \tag{31.b}$$

$$E_{k+p} = x_{e(k+p)}\hat{\beta}_e \; . \tag{31.c}$$

3. The Updating Procedures in Detail

Application of the results of the previous section yields a set of projections based on observed historical data. These projections answer the question "If present trends in enrollments and underlying causal factors remain unchanged, what enrollment configuration may we expect K years hence?" The model now gives the user an opportunity to simulate future enrollments under changed assumptions regarding trends and underlying factors. The present state of development of the model acquires translation of the new assumptions into the numerical terms of enrollment; and these assumed future enrollment configurations are then taken as the basis upon which new projections are developed.

As has been stated, the user has at his command two modes of incorporation of the new configuration: in one case, it is assumed that the input future configuration is representative of a new and continuing trend; in the other, the assumption is that the input future configuration is a one-time occurrence and that henceforth, the underlying factors of and trends in the parameters of the modeled system would revert to their original states. These modes are called dynamic and episodic updating, respectively. Since the second requires no "curve-fitting," it is by nature the easier understood, and will be discussed first in the discussion to follow.

3.1. Episodic Updating

Referring to Figure 5, assume that the crosses represent observations on "number of first-time freshmen in curriculum 1" for the years 1,2,3, and 4 — the assumed "historical" years of this example, and that the points represented by dots are projected values of "number of first-time freshmen in curriculum 1" for the years 5,6,7, and 8. In essence, the regression line (the heavy line in the diagram) was fitted to the crosses, and the projected points placed on the line above the selected positions on the time axis.

The shaded square above the point representing the year 6 projection is the "change" being instituted in a projected value by the analyst. He desires to estimate the impact on future enrollments if there is a large, one-time influx of students in year 6 into curriculum 1, and thus "episodic" is to be the method of updating the subsequent enrollment projections. In an episodic update, the model does not recalculate new values of first-time freshmen in curriculum 1 for years 7 and 8, but reference to the recursive nature of the model (equation 13) indicates that the effect of this change will manifest itself in the projected values of total students for not only year 6, but year 7 and year 8 for this and all subsequent iterations. The model

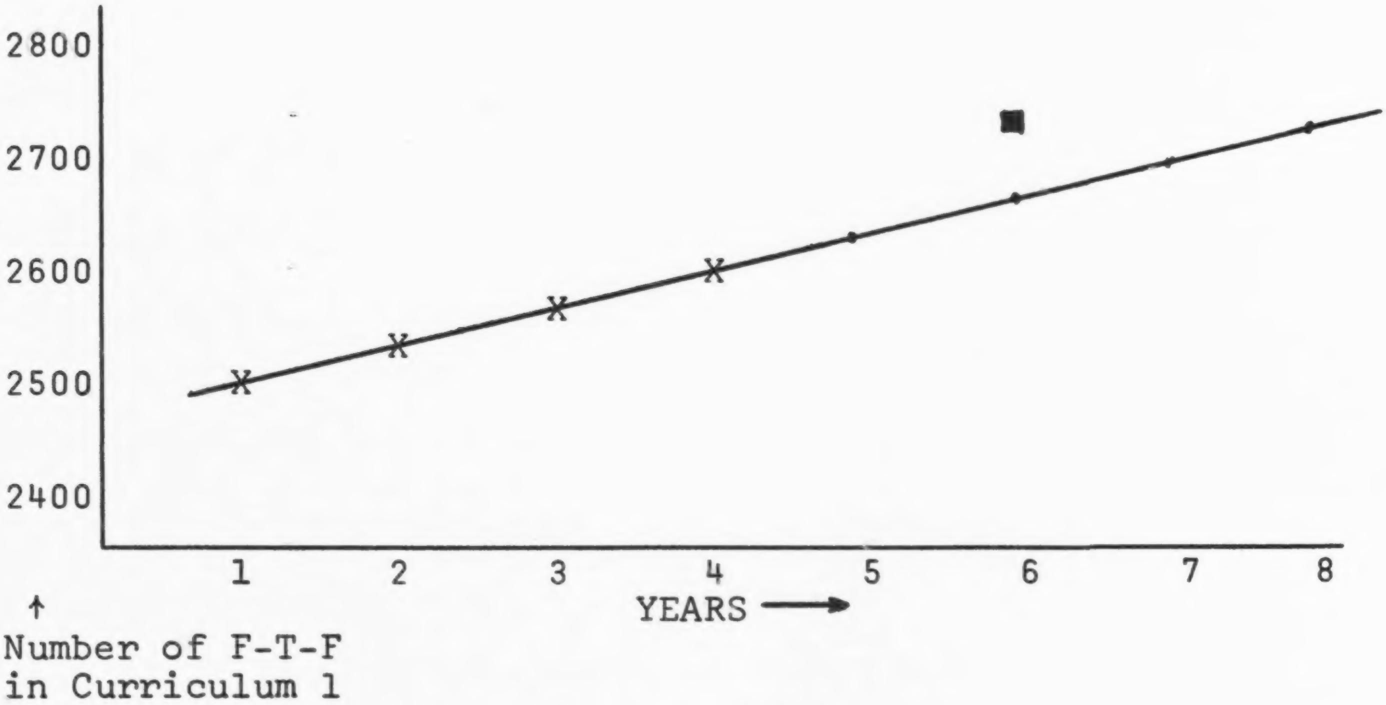

FIGURE 5
THE EFFECT OF AN "EPISODIC UPDATE"

performs no calculations on those years before the changed year, since the past is not affected by the future.

3.2 Dynamic Updating

As opposed to the characteristics of the episodic update, the basis of the dynamic update is one of allowing the user the option of incorporating changes in projected values as actual observations on the dependent variable. When an input value is used as an observation, it cannot be expected that the regression equation fitted to the new and the (chronologically) previous points will pass through the former. The changed value, when used as an observation for regression, becomes merely another point in a data set which indicates trends or lacks thereof in the value of some dependent variable.

As a very simple example of dynamic updating, assume that Figure 6 depicts, as in Figure 5, four years of hard data and four years of projections of numbers of first-time freshmen in curriculum 1. Again, the crosses represent hard data, the dots projected values, and the shaded square the change being instituted by the model user: the heavy line represents the original regression line based on the hard data (years 1 through 4).

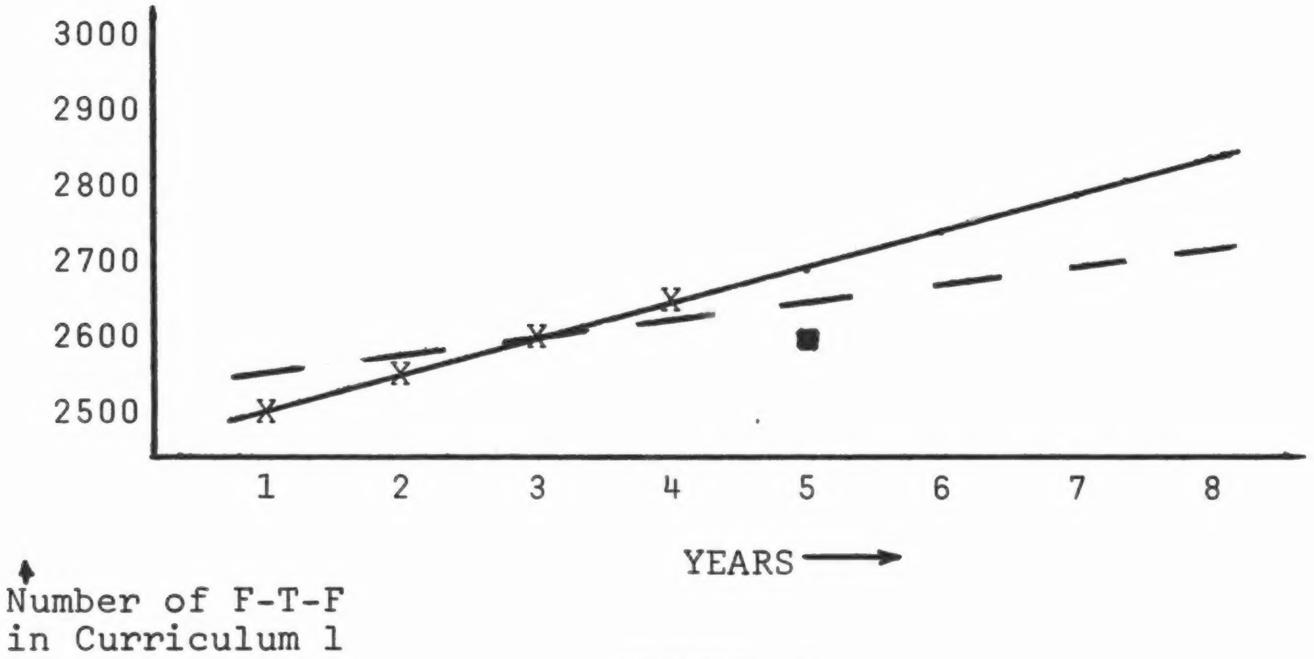

FIGURE 6

EFFECT OF A DYNAMIC UPDATE

Assuming, for expository purposes, that the regression model being used for projection of first-time freshmen is of the form $y = b_0 + b_1x$, simply the equation of a straight line. Then if a straight line is fitted to the shaded square and to some of the points to the left of it (on the original regression line), it is obvious that the slope and intercept of the new regression will differ from those of the original. A question thus arises as to the points, in addition to the changed projected value, to be used in the calculation of the new regression coefficients -- and the weighting of the proposed value in relation to the weights of the other data. As will be seen, the latter two problems are not mutually exclusive.

Generally speaking, it would be expected that the analyst has some reason behind his input of the changed value, implying that this value is somehow "important" to the planner in its effects on future enrollments. Thus the new input value may merit greater weight in the recalculation of the regression coefficients than is accorded the other data to be used in the calculations. Three possible approaches to the weighting of the new value might be as follows:

(1) If the subsequent set of projections is to be made on the basis of all data from (relative) years 1 through to the changed value, each observation would be weighted exactly as every other. However, each time an additional point is used as data, the effect of all points is decreased, the extent of this decrease depending upon the total number of points taken as data.

(2) The new value's importance is implicitely increased by deletion of the first "few" observations originally used for the calculation of regression coefficients. While the new coefficients would still be based upon (in our example) 4 observations, the latter would include all values up to and including the new value. Thus "few"

is defined specifically as that number of observations which, when dropped, will leave as "hard" data the same number of points originally used for calculation of regression coefficients. It may be well to note two important facts at this point: first, that henceforth "hard" data will mean those data upon which the regressions are based rather than actual historical, collected data; and second, that projected points used as hard data have the same equation associated with them as with the original fit to the collected data. Thus, in Figure 6, it is not necessary that the change being input by the model user be instituted in the first projected year subsequent to the data of years one through four: the change might have been input in year seven, using the collected data of year four, and the projected points at years five and six in conjunction with the input value of year seven for regression. The trend characteristics developed for the years one through four data were transmitted to the points projected for years five and six. As can be seen, the effect of the changed value on the calculated trend would not be as diluted as it was in Case 1, and the calculated regression line would be, in effect, composed of the trend inherent in three collected data points and one assumed or "changed" point.

(3) To include the capability of more complex weighting, the model might use weighted regression, where the solved normal equations are rewritten $\beta = (X'VX)^{-1}X'VY$ where V is a square matrix of weights. With this technique, the changed value could be made as "important" as desired in terms of shifts in the regression line as a result of its inclusion.

The approach outlined in (2) above is presently being used as the weighting method. The most important factor in this choice was from the point of view of the user of the model, rather than from considerations of mathematical validity. With method 1, the user could, in fact would be forced to, perform complicated calculations in order to give the newly entered value the desired importance. It seemed that the weighting implicit in the deletion of the most remote observation(s) was, for small numbers of observations, large enough to satisfy the user, and obviate the need for him to enter into complicated calculation of the new value required to, in essence, weight itself. Method (3) was chosen originally, but the adaptation from batch-processing to time-sharing use of the model dictated that the computer memory requirements of the latter be kept relatively small. Since Method (3) does offer the greatest flexibility, however, it is recommended that it eventually be incorporated into the model.

Assume that projections are to be made on the basis of the observations on two independent variables: a "dummy" variable related to the intercept of the regression line, and "time." The model assumed for the observations of Figure 6 is of this form, and thus the regression lines of that figure have slope and intercept, but no curvature. The original matrix of observations on the independent variables (the X matrix) is then of the form

$$X = \begin{bmatrix} 1 & 1 \\ 1 & 2 \\ 1 & 3 \\ . & . \\ . & . \\ . & . \\ 1 & u \end{bmatrix} \qquad (32)$$

where, again, u is the number of observations — 4 in our example. Following the procedure outlined in Method (2), the changed value for some year "p" now becomes the u^{th} "observation" on the dependent variable, and the previous u-1 (=3) points are used as the other dependent variable observations. The X matrix must be changed to

$$X = \begin{bmatrix} 1 & p-u+1 \\ 1 & p-u+2 \\ 1 & p-u+3 \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ 1 & p \end{bmatrix} \tag{33}$$

or, for p=5 and u=4 as in Figure 6;

$$X = \begin{bmatrix} 1 & 2 \\ 1 & 3 \\ 1 & 4 \\ 1 & 5 \end{bmatrix} \tag{34}$$

The coupling of the X matrix of (34) with the "observations" on the dependent variable for years 2 through 5 results in the dashed regression line of Figure 6. The points on this line subsequent to the changed year represent the new set of projections, and have a different trend than that inherent in the points of the original regression line. The changed value has been taken to be indicative of a continuing trend, and the new regression line, in effect, answers the question "if the changed value had simply been an actually collected datum, what would have been the calculated regression line for this dependent variable, and what effect on the enrollment projections would this line have had?"

Each time this process is repeated, we say that an "iteration" of the model has been performed. Changes may be made in successive or non-successive years, as long as the latter are in simulated chronological order. Thus changes might be made in (relative) years 5,7,7,8, and 10.

The dropping of the "oldest" data points brings up a problem in all cases for which the regression line does not fit the dependent variable observations exactly. Previous examples have shown the observations of the dependent variable to be a segment of a low order polynomial expression — that is, a straight line fits the data exactly. It is not expected that such will be the case, and we may assume that the dependent variable observations might be as shown below, with the solid line representing the regression based on $u=4$ observations, the crosses being the actual observations, and the dots representing projected points on the latter regression line.

The variable under consideration might be "numbers of first-time freshmen in curriculum 2" — and none of its projected values are being changed by the model user for this particular iteration. If, however, changes are being made in "numbers of first-time freshmen in curriculum 1", the structure of the model is such that a new regression line will be calculated for the curriculum 2 freshmen. With no changes being instituted in the latter, it should be expected that none of its projected points change. The new regression line will be calculated on the basis of the same years' data as the variable actually being changed; using the example of Figure 7, these years would be 2,3,4, and 5. Using the crosses (in Figure 7) at years

2,3, and 4 as the first three "observed" points, and the dot at year 5, originally a projected point, as the fourth, it is apparent that the best fit to the latter four points is the dashed regression line — resulting in a new set of projections for years 6,7, and 8 which differs from the original — an undesirable situation.

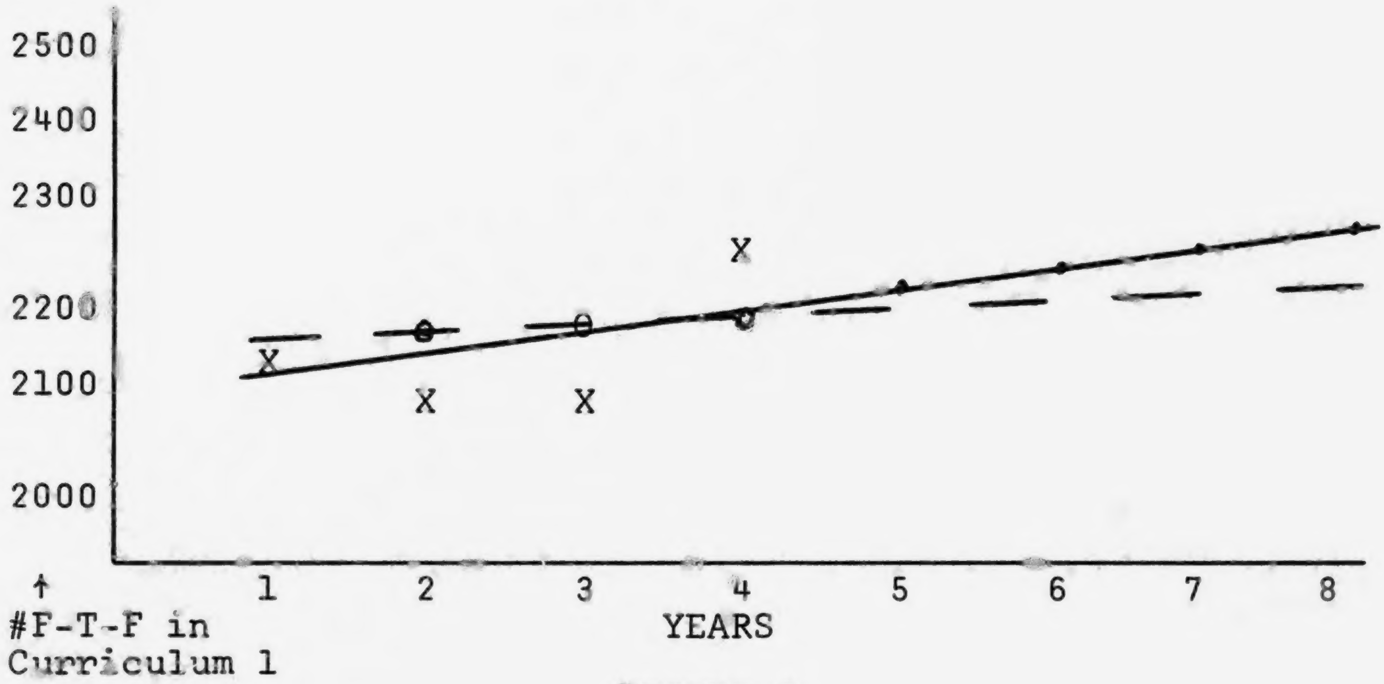

FIGURE 7

DYNAMIC UPDATE WITHOUT SMOOTHING

The programmed procedure for alleviation of the situation above is as follows. Prior to projection for each iteration, the "observations" upon which the regression coefficients are to be based are "smoothed": they are placed directly upon the previous regression line. If, in the next iteration, no "changes" are desired for a given variable, the "smoothed" data are taken as observations — and dropping the "oldest" points does not change the properties of the new line from that calculated previously. Thus the newly projected values will equal the old, as they should. Thus in Figure 7, the heavily shaded circles represent the original data smoothed — that is fitted — to the calculated regression line: and since these points now have exactly the same characteristics as the projected points on that line, the use of a combination of the former and the latter in the calculation of a new regression line will yield the old line. In the case of dynamic updating of an element for which a change has been made, the same reasoning holds: the data upon which the regression is to be based must be smoothed to assure a lack of confounding of the projections based on the change, by the changes in the regression line due to the use of unsmoothed data. It may be noted, too, that it is not only in the case of straight-line projections that the smoothing procedure must be followed.

C. Data Requirements of the Model

The previous section has presented a sophisticated mathematical model; however, the validity and informational content of its output are a function of the validity and informational content of the inputs to it. Thus, while the model may rearrange the input data in a manner more amenable to analysis, output validity would require that the output be no more disaggregate than the input data. Therefore, this (or any) computer model does not produce new information: it can only rearrange old information, and present it in a more useful format. However, this procedure must be prespecified before the computer can begin processing the data.

The model under consideration produces enrollment projections. A large part of the projection process is, in essence, that of fitting curves to a variety of different sets of data observed over time and extending these curves into the future. New information is not produced, but estimates of future enrollments are made on the basis of that which has been observed in the past. Therefore, information on disaggregated projection of enrollments must have its counterpart in past data. The need of educational planners for enrollment projections must be balanced between the desire for a meaningful and comprehensive format, and the need for enrollment projections in highly disaggregate form so that planning based on these projections can be made operational. The person (or persons) interested in the educational system's future faculty, facility, and budgetary needs is not aided by a single "lump" projection of total number of students in the educational system for some future date. His immediate questions are "will more students be attending two-year colleges? Will the proportions of students allocated to each curriculum be the same? Will my sector (public or private) gain in enrollment proportionately with present enrollments, or will another sector be flooded with students who might have entered the one with which I am concerned? Will the programs presently being instated for aid to the educationally and economically disadvantaged show significant effect?" The prerequisite to use of a model which will aid in answering these questions is the input of data whose disaggregation and information content corresponds to those outputs which will, in fact, be such an aid.

Inputs to the model constructed, since the latter is a prototype, are indicative of the data requirements of the model which might ultimately be used as part of the planning function. Since it was deemed desirable by the educational planners consulted that projections of future numbers of students be both classified and categorized (although the terms used may not have been exactly the same), input data require both a major classification scheme and a set of categories of characteristics of students. In addition, since the worth of the concepts surrounding transition matrices and the information contained in the latter were recognized, it was required that historical transition matrices be obtained.

While the form of the input data is somewhat flexible, there are certain minimum data required for the running of the model, whose information content is rigid. From the mathematical structure of the model, and specifically the recursive relationship which describes the cycling or aging process, we know that the total population of the educational system, grouped both by the major classification scheme and the categories of characteristics, is cycled through a transition matrix to yield a similarly classified and categorized matrix of groups of students who remain in the educational system for the immediately subsequent period. To the latter matrix are added two similarly classified and categorized matrices: one of first-time freshmen and one of upper-level entrants. The resulting sum is the total population of the educational system for that subsequent year, by classification and category of characteristic. In order for this process to be carried out by the model for projected years, the historical data must give information which allows the components being acted upon by the process to be developed. Since this development involves the projection of historical data, the matrices referred to above must be input for the years in which the historical data were gathered. Specifically, for each year for which historical data is to be collected, the analyst must obtain:

(1) a matrix of first-time freshmen, classified and categorized by the major classification scheme and categories of characteristics, respectively, desired by the analyst as output groupings;

(2) a matrix of upper-level entrants, also classified and categorized as were the matrices of first-time freshmen;

(3) a matrix of the transition proportions between each pair of components of the major classification scheme and between these components and the "outside world", i.e., a transition matrix.

It might be noted parenthetically that if the model is to be used on a semesterly or quarterly rather than a yearly basis, the above matrices would have to be collected for as many periods as were being used for observation of historical data. Thus for five years of data on a semesterly basis, ten sets of the above matrices would be required.

One additional segment of student data is required for completeness. As is stated in the description of the recursive relationship, the processing must start at some point. Because the process is recursive, a logical starting point is one at which a matrix of total students, classified and categorized according to the major classification scheme and categories of characteristics desired for analysis, is available. Thus it is imperative that such a matrix is collected for a single year of the historical data; and it is worthwhile that this year be the first year for which complete historical data are available. If this matrix is developed for the first year, one of the validity checks on the model, designated "concurrent validity," can be made. In testing concurrent validity, we are asking the question "does the model (in terms of the output it produces) represent the present and on-going function of the system being modeled?" If some of the historical data are estimates, there may exist inconsistencies in them. The extent to which these inconsistencies exist would be determined by comparison of the simulated results for the historical years with that which is known to actually have happened. To reiterate then, the next data requirement would be

(4) for the first period for which complete historical data are available, a matrix of total students classified and categorized as were the matrices of first-time freshmen and upper-level entrants.

Also required as input are data concerning the independent variables upon which the regression coefficients and ultimately the projected matrices are to be based. At the very least, the values of all independent variables through time must be input — for both the years to be projected and the historical data years. For the models run in the time-sharing mode, as has been stated, core size limitations were such that the simple reading of the independent variable values over time would have required too many subsequent calculations to make the program of feasible length. Thus the required calculations on the observations on the independent variables are performed separately from the computer program itself, and read into the computer in processed form (where a set of calculations must be performed for each set of independent variables which might, during a given iteration of the model, be used as "observations."). At the same time must be input each year's values of the independent variables so that having calculated the regression coefficients, the projected values of the elements within the necessary matrices can be calculated. It is in the models run on the larger core computers that only the sets of values of the independent variables need be input, since the calculations required for them will be performed by the computer program itself.

As was indicated at the start of this section, the form of the input data is somewhat at the direction of the analyst. Study of the actual program listing by those knowledgeable in the FORTRAN language will show the exact input format presently required: this formating is easily changed by the programmer. Thus, for example, although transition matrix elements are presently read in percentage terms, the elements might be read in numerical flow terms and converted by a short subroutine into the required percentages. In another instance, the "starter matrix" (classified and categorized matrix of total students for the first year for which complete historical data are available) might be read as a vector of numbers of students by classification, and associated with each element in this vector a vector of percentages would be read to convert this (in essence) starter vector into a starter matrix. Because of the great number of possible forms in which the data might be collected, all forms could not be allowed for — and thus a single one was chosen which best fit the needs of the researchers and the data available. Certainly if the characteristics describing students are not all of the same variety — that is, if some are constant and some are variable (as discussed in this section concerning evolution of the prototype) some data might be read as numbers of students and others might be read as percentages of students. The important point to keep in mind is that regardless of the input form of the data, they must ultimately be of the form stated above.

D. Evolution of the Model

As was stated in the general introduction, the development of the model under consideration involved a continuous learning process on the part of all involved. Many of the more tangible results of this learning are embodied in the computer programs of the model.

1. Concept Reformulation

As originally conceived, the pilot model would be small in terms of the number of components in the major classification scheme and the number of categories of characteristics describing the student population of the educational system. It was expected that many of the operating characteristics of the pilot model would be incorporated in a more encompassing full-scale implementation, but that the number of components in the major classification scheme of the latter would be much greater than the number in the pilot model. Thus, it was indicated that a major classification scheme of two-hundred components was within the realm of practicality in view of the capabilities of present-day computing facilities, with perhaps one-hundred categories of characteristics for description of student populations. In view of the tremendous data needs of such a large model, the four pilot applications of the model attempted

(Statewide, CUNY, HVCC, RPI) had eight, six, twelve, and thirty components in their respective major classification schemes, and nine, twenty-four, two, and eighteen categories in their respective categorization schemes. Since one of the facets of the analysis of the output from these models was that of studying the trends in transition matrix elements over time, it was found that the output of a given run could reach fairly large though readily analyzable proportions. Ultimately, however, it occurred to all concerned that analysis of a chronologically-ordered array of, say, ten transition matrices from a model with a major classification scheme of two hundred components would involve some four hundred thousand values: certainly not an amount amenable to rapid analysis by a single person or small planning group. Moreover, with the addition of a one-hundred by two-hundred element array (for each year) to describe the characteristics of the student population, 200,000 more numbers await analysis, bringing the total to more than 600,000 or six-hundred large pages of computer printout, assuming twenty columns of fifty numbers each per page. Of course, all this would be for one iteration of the model, and even selective printing would yield a prodigious amount of output at large overall cost. To keep the results useful, the course taken was that of considering a series of less-encompassing models, each permitting analysis of different combinations of components of that which might be termed the "overall" classification scheme of the educational system — a scheme whose components would include the most disaggregative delimitations of the system. A series of smaller models would not only be more amenable to analysis, but would give more accurate results due to their aggregative nature. In these studies the structure of the model would be identical — only the "labels" associated with the classifications and categorizations would change. While this actual use of this new concept some information would be lost — it would not now be possible to model all the interrelationships among the components of the overall classification scheme at once — the gains in analytic efficacy would appear to far offset the losses, particularly in light of the fact that some of these interrelationships might not be of prime importance to the educational planner. In sum then, it is expected that the size-range exhibited by the pilot models developed will more nearly approximate the size-range of any model actually used as a full-scale planning aid, as opposed to the rather large models previously envisioned as full-scale. "Full-scale" has taken on a new connotation of "flexibility, capability, and utility," as opposed to that of mere size.

2. Changes in Inner Structure

A second change in the concept of the model has direct bearing on the evolution of its inner structure. As originally conceived, the model would have associated with each element in a vector of students by classification a second vector of percentages representing the proportions of that classification's students falling into one or more sets of mutually exclusive and collectively exhaustive categories. These vectors of percentages were projected as entities separate from the vectors of first-time freshmen and the matrices of transition proportions. Determination of the number of students in each category for a given projected year and component of the major classification scheme was then made by multiplying the total number of students in the component by the projected vector of percentages associated with the component.

Since at the beginning stages of the research less consideration was given to the simulative potentialities of the model, all vectors of percentages could be considered as a separate projection problem since only one iteration of the program needed to be made for the entire set of desired enrollment projections. The researchers became aware however, that the needs of the educational planners were such that the simulative capability would be highly important. Therefore much effort was devoted to the introduction and explanation of the model as a simulative device with the capacity to aid in evaluation of policy decisions and exogenous variable changes as they related to projected college and university enrollments.

2.1 Introduction of the "Episodic Event"

One of the main operating characteristics of the simulation model which aids in the evaluation of proposed alternatives and the analysis of the impact of chance happenings is that of the process of recalculating the regression curves for projection on the basis of projections input by the planner. The assumption implicit in this procedure is that the projection being input by the planner is to be representative of some continuing trend. However, as familiarity with the model on the parts of the planners grew, a question arose as to the desirability of guaranteeing that input changes would imply changing trends.

During one demonstration of the model, the researchers asked for the input of "what-if?" type questions from the floor: the event decided upon was that of a one-time influx of black students. In order to effect this changed projection, the components of the major classification scheme in which the influx would be distributed were first determined (by querying the planner responsible for the original question) and the numerical value of this influx was spread in correct proportion over the vector of first-time freshmen. A calculation then had to be performed to determine the change in the distribution of Negroes. At this point, the obvious fact was brought out that since the percentage of Negroes had changed for the freshmen of a particular year, modeling validity would require that some change occur in the percentage distribution of Negroes for the sophomores of the subsequent year — and that this change would, of course, be a function of the original change in the percentage distribution. The model at that time could not handle adequately this type of a change.

2.2 Matrices of Students

In expanding the capability of the model to assimilate a "what-if" question of the episodic variety, a major change was made in the structure of the model: instead of a vector of classified students whose elements were each associated with a vector of categorizing percentages (again, as these terms have been defined for specific usage in this report), the vector of classified students was expanded into a matrix of students grouped both by classification and category of characteristic (See IIA.1., General Overview, p. 14). Thus in the case of first-time freshmen, a matrix exists where had previously existed a vector — and this matrix was then projected to give not only the numbers of expected first-time freshmen by classification, but also by category of characteristic. This change in the structure of the model set the stage for the ability of the model to simulate the episodic event. When the additional influx of students is input, it is input in raw numerical terms — and there are no percentages upon which calculations must be performed. However, if the simulated students are described by more than one characteristic, this same influx must be input into each. Thus, for example, if one-hundred males are added to the "gender" characteristic of classification 1, and "age" is a second descriptor of the simulated students, then the hundred males added to classification 1 must be distributed among the categories of age under classification 1. The aging process then becomes the cycling of a matrix of students through a transition matrix, rather than the cycling of a vector through the transition matrix. As seen in the section concerning the mathematical derivation of the model, the assumption of independence between student characteristics and transition probabilities is highly visible in this newer though not yet most finalized structure, since a vector associated with each (fixed) category of characteristic is cycled through the same transition matrix.

2.3. Constant, Regularly Variable, and Irregularly Variable Characteristics

The most recent advance with respect to categorization of students come with the realization that while categories such as male, female, and/or "New York City resident" lend themselves quite readily to the cycling process described in the mathematical derivation, categories within such characteristics as "status" or "age" do not. The fact that a student attends college on a part-time basis during one time-period does not necessarily mean that he will do so in the next. The latter type of characteristic is more correctly included in the section of the model devoted to student flows — e.g., it should be included in the major classification scheme rather than as a characteristic. If, however, flow data on the descriptor in question are not available or, if available, make the major classification scheme too large for convenient analysis, certainly some course of action must be taken. The course chosen was that of reinstating the separate projection of vectors of percentages for each component of the major classification scheme as had been done originally. To sum up, those characteristics of students which are relatively constant are cycled through the transition matrix, while those which can vary in an irregular manner are projected separately in percentage form, and later converted to numbers of students by multiplying the number of students in a classification by the vector of percentages associated with that classification. A third type of characteristic, one which varies in a regular manner through time, must be processed as a function of the manner in which it varies. Thus, for example, in a model based on one-year time periods age categories may be spaced in one-year intervals for simplicity, and these categories cycled through the transition matrices as in the case of the gender or geographic origin categories. However, after this aging process, the number of students in each age category would have to be shifted to the subsequent age category so that cycling through the transition matrix would also have as a result all students being one year older. As can be seen, the processing of the characteristics of students would depend on the characteristics themselves, and a methodology has been developed for each type of characteristic.

3. Independence of Design from Mode of Operation

A final consideration to be made explicit is that of the independence from mode of operation for the prototype model developed. Originally, only the batch-processing mode was considered. In an effort to speed programming and debugging, use was made of a time-sharing computer service. It should be stressed that this "man-machine interaction" is a highly desirable feature in the use of a simulation model since alternatives may be proposed and evaluated almost instantaneously. Perhaps the greatest usage of the model would be found in a "real-time environment — that is, during actual meetings. Since it was realized that the interaction between man and computer that had been by far the most important contribution of the time-sharing system was an important capability for a simulation model, the model developed for the analysis of a particular institution in a "batch" mode was given an input-output structure adaptable to a time-sharing mode; an identical structure is maintained in either mode; the model merely contains the necessary input/output modifications necessary for communication in each mode. The same questions are asked, and similar responses required of the model, in either of the above two modes. While in the time-sharing mode the commands and responses of the planner would be typed directly into the computer via the teletypewriter, the batch mode requires a deck of "control cards" which for general usage might be pre-printed with the queries of the program and punched just prior to running of the latter. Certainly several differing versions of the simulation operating in both a batch and time-sharing mode could be utilized concurrently. The particular mode of operation utilized is solely dependent upon the requirements of the user rather than any exigencies of the simulation.

E. An Explanatory Run of the Prototype Model

1. Introduction and Overview

The explanation on the following pages is concerned with the output of the model representing the New York State educational system as a whole;* and for facility of discussion, specific referral will be made to the major classification scheme and categorizations used. A listing of the results of the run under consideration is given at the end of this section, and will be used as the vehicle of the discussion. The commands and responses of the model user are darkly underlined to distinguish them from the questions and responses of the model itself: it will be noted that the man and the computer are instructed to communicate in English wherever possible and efficacious, although the mode of communication is extremely flexible in computer models in general.

The data for implementation of the statewide pilot model were gathered from a great many sources, most of which were compiled over the past six years by the State Education Department, and particularly the Office of Planning in Higher Education. While a portion of the data required were available in precisely the correct form, much did not exist — particularly those data concerned with transition proportions. As a result, many subjective estimates and assumptions were made, just so that a viable data set could be developed: the reader is thus cautioned that the results shown in the output listing are not meant to represent expected New York State higher educational enrollments for the coming years, but are meant to represent the form, content, and usability of the results and model, respectively.

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*Strictly speaking, only the data are the determining agents in "as a whole".

The subsequent discussion describes in detail the requests for information, responses of the user, and type of output involved in a "typical" run of the prototype model. Generally speaking, the first iteration performs all projections automatically for a number of years specified by the first user input. The first few requests by the computer for information thus involve giving the user the option of printing or not printing portions of the projected results. The "change procedure" of the model is then encountered: here are chosen the parameters to be changed and the new assumed future values. Subsequently, the user chooses the mode of updating the projections (dynamic or episodic) and is returned to the section of the model which requests information on those parameters and variables to be printed.

The actual printout begins on page 97. The discussion follows exactly the order in which the communications noted above are arranged. Before reading the text, it may be advisable to skim the printout to gain at least a sketchy idea of the man-machine dialogue therein.

2. Discussion

The first question asked of the user is the number of years he desires to have projected in the first iteration of the program. Input of the number 8 not only answers the question but determines the "futuremost" year to be projected: with historical data for the years 1965, 1966, and 1967 being the foundation of the projections, the "futuremost" or "max" year as it will be called, is 1975. For the program under discussion, up to twelve years might be projected — a max year of 1979. It might be noted that the three years' historical data is not a fixed requirement that, in fact the more years' data used as the basis of the projections, the more statistical confidence can be put in the projections.

The user next must choose whether or not to print the data concerning first-time freshmen. Since he is viewing the results of the first iteration of the program, he would, in general, desire to see the enrollments projected solely on the basis of the historical data before they are altered by alternative assumptions which might be made for the future. In addition, the first iteration is the only one in which the opportunity is presented for printout of the historical data. Since the latter never change, they need be shown only once.

Wherever possible, the format of the printout has been made to correspond closely with that found in already-existing sources of data. After setting up column headings corresponding to the major classification scheme which in this particular case is the combination of college types, controls, and levels pictured in Figure 8 on the following page, eleven years of "first-time freshmen by classification" are printed — the three years of historical data and the eight years of projections requested. The second group of numbers is merely a set of aggregations of the above figures by year for all eleven years: note for example that for any year, PUB-2YR (public two-year) is the total of two-year public career plus two-year public transfer program students for that year in the first group of numbers.

The next question asked by the program regards printout of the total number of students in the educational system, again grouped according to the major classification scheme, for the projected years and — in the case of this, the first iteration — for the

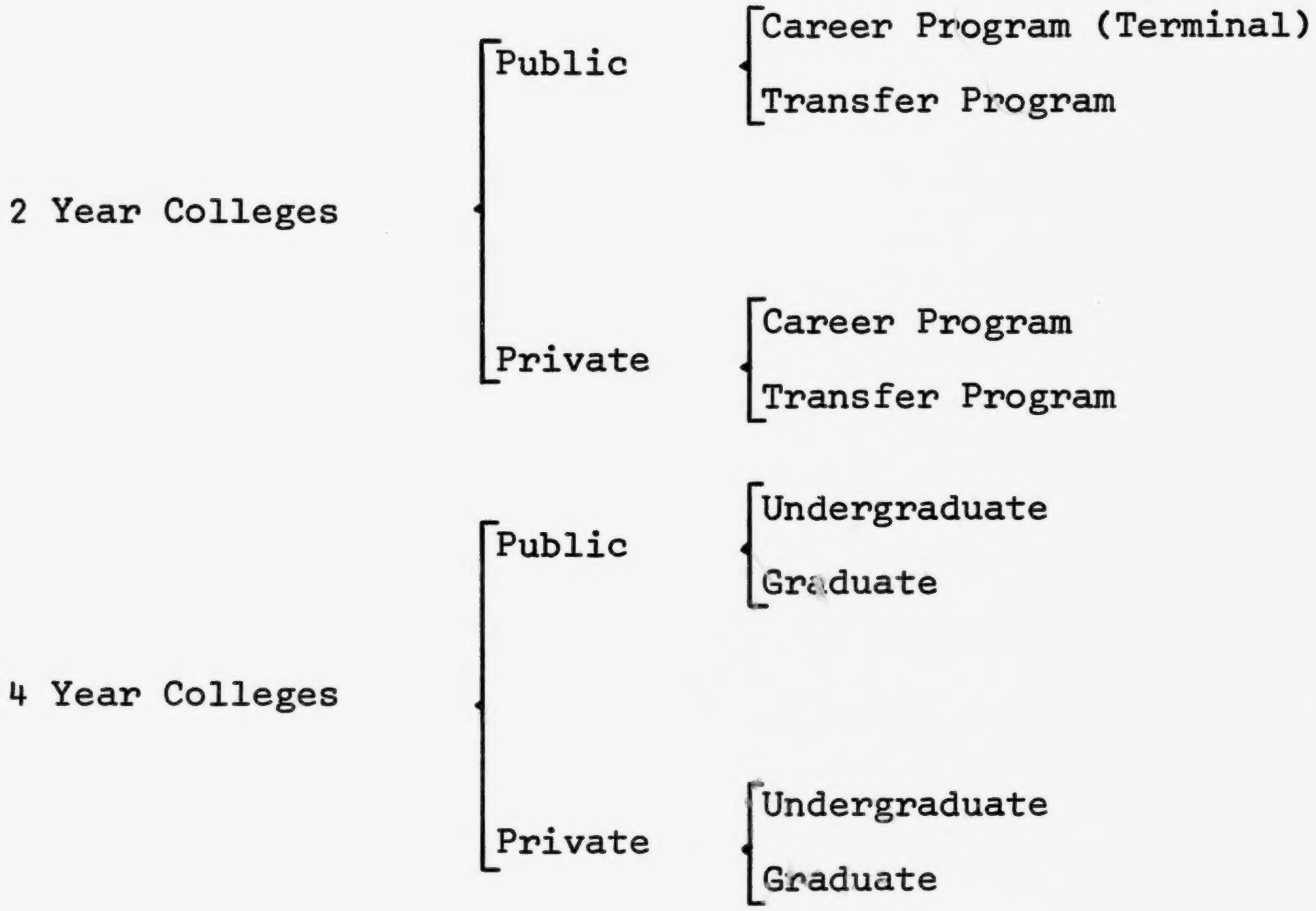
2 Year Colleges
Public
Career Program (Terminal)
Transfer Program
Private
Career Program
Transfer Program
4 Year Colleges
Public
Undergraduate
Graduate
Private
Undergraduate
Graduate

FIGURE 8

THE MAJOR CLASSIFICATION SCHEME:
STATEWIDE MODEL

historical years. The user types YES on the teletypewriter, and the desired printout follows. Again, the major classification scheme is printed as a convenient reference, and again are prespecified aggregations printed for each year. Although it is not necessary that the aggregate groupings be the same as those for first-time freshmen, they are the same for this particular model. Again, it is desirable that "total students" be printed for purposes of comparison with the results of later iterations.

The user is now queried as to whether he desires output concerning upper-level entrants, and he must again answer either YES or NO. (Actually any answer other than YES is interpreted as a negative response.) Upper-level entrants are grouped by the major classification scheme, although no aggregation of them has been carried out. However, aggregation schemes such as those used in the first-time freshmen and total students printouts are not difficult to incorporate, and may be installed if desired.

As yet, no mention has been made of the categories of characteristics by which students are described. Following the optional printout of upper-level entrants, the user may request such a printout for total students by answering YES to the question "PRINT STUDENTS BY CHARACTERISTIC?" Data regarding first-time freshmen and upper-level entrants by category of characteristic are available and the program can be modified to print this information.

If the user desires printout on total students by category of characteristic (and major classification scheme components), he will then be asked to input the number of years of output desired, and the specific dates corresponding to that number of years. In addition, the user is reminded of the earliest year available to him for printing. Thus the question of "how many and which years" is answered by typing 3 (for three years of output) and the specific years chosen for viewing, 1967, 1970, and 1975. Two facts must be noted at this point: first, that the user is reminded of the earliest year available to him for viewing — in the first iteration it is the first year from which historical data have been utilized, while in subsequent iterations, it is the changed year, since output from before the changed year would exactly equal that from the previous iteration. Secondly, that in comparison to batch-processing systems in general, on-line printing is quite slow. The six-line per minute typing speed of the teletypewriter makes it imperative that the user have the option of specifying some portion of the output which is most critical to his needs, and not printing all those results which he might. For some segements of the potential output, a considerable timesavings can result from this option: the three years' results shown took approximately six minutes to print; a total printout at this point would have taken about 16 minutes.

The printout of total students by classification and category of characteristic is preceded by the printing of a key so that each years' set of numbers can be understood. Thus the nine categories of characteristics are read from the key: the categories are male, female, full-time, part-time, U.S., foreign, residence in same county as school attended, residence in same economic area (excluding county) as school attended, and finally, residence in New York State other than economic area of school attended. The characteristics are sex, status, and geographic origin; since the key states that these categories are found "reading down," the first row of the printout represents "male," the second row, "female," and so on. Thus, for example, the upper-left-hand corner element of the first (1967) matrix of values indicates that in 1967 there were 34,478 males in career (terminal) programs in the State's two-year public schools. Furthermore, it is seen by the third (1975) matrix printed that there will be 63,606 such students by 1975.

Having printed the total students by category of characteristic for the desired years, the user must answer YES or NO to the question of whether or not to print any transition matrices. For the reasons iterated in the case of categories of characteristics, the user can choose the specific years he is most highly interested in, and have those years only printed out.

Accordingly, he answered YES to the question of whether or not to PRINT TRANSITION MATRICES, and three years were indicated: 1968, 1970, and 1975. Again, as with all printout on the first iteration, the earliest year available is the first year of historical data.

In viewing the printout of the transition matrices, the user must recall that the quantities within them represent flows or movements of students between all the components of the major classification scheme delineating the possible student locations within the educational system. Thus before actual printout of the matrices themselves, the user is reminded that the row headings are those of the first eight columns, ordered in the same manner as the order of the column headings. It may be well to note that this ordering is exactly the same as that inherent in the printout of first-time freshmen, total students, and upper-level entrants. The headings (understood) for the rows, and the abbreviated headings for the columns then represent, in order, two-year public career (2PC) two-year public transfer (2PT), two-year private career (2PRC), and so forth. The last two columns of the matrix of transitions should be interpreted as "those who leave the educational system without a degree," and "those who leave the educational system with a degree," respectively.

While for computational purposes the elements within the transition matrices must be in percentage form, it was felt that for purposes of analysis, more meaning could be gained if printout were in terms of "numbers of students" making the component-to-component transitions, and this conversion is made prior to output.

Associated with each year is a transition matrix. The convention adopted was that the associated year would be the "first term" in the actual academic year. Thus the first matrix printed, that for 1968, represents transitions over the academic year 1968-1969. In this "1968 transition matrix," the numbers represent projected inter-component flows of students. Reading across the first row of the matrix, of the total number of students in two-year public schools, in career programs in 1968, 22,597 remained in that classification for the start of 1969; 3,507 switched to transfer programs within the two-year public schools; 133 remained in the career program but switched to private schools; 133 switched to the transfer program at private two-year schools; 999 became undergraduates at public 4-year colleges; none became graduate students, 564 became undergraduates at private four-year colleges, 32,651 left the system with a degree. If all the latter numbers are summed, it will be found that the result is 66,593 — the number of two-year public career students in the educational system in 1968 as previously printed. Analysis of each of the rows in turn, (two-year public career, two-year private transfer, and so forth) would be performed in the same manner, for each transition matrix.

Transition matrices are the last projected data printed by the prototype at present. At this point we may say that the first iteration of the program has ended: a complete set of projections has been made, although to save printing time, only the "important" ones have been viewed. The word "important" has been put in quotes since the printout being shown was the result of a run made purely for explanatory purposes. In an actual planning situation, however, it is assumed that the user of the model will be concerning himself with specific portions of the total potential output, and thus there will be different measures of "importance" associated with different portions of printout in different runs, and, for that matter, iterations of the same run.

The user is now queried as to whether he desires to make another set of projections, implying the question "are changes to be made in projected values for analysis of their impact on system variables?" Put another way, "does the user wish to evaluate the effect on projected enrollments of some policy change(s), change(s) in the environment exogenous to the educational system, student behavior change(s) or resource allocation change(s)?" In the present form of the model, these changes would be input in terms of changes in the quantities of first-time freshmen, or upper-level entrants for a given year or years; or in terms of changes in the transition proportions for a given year or years. This change procedure is such that only the values of a single year's projections can be changed in a given iteration — although the use of the dynamic updating procedure allows for changing overall trends by insertion of only one years' changed values.

In view of the above, the user having answered YES to the question of whether another set of projections was desired, the program then asks for that year in the future for which a set of changes is to be made. Before explaining the output listing any further, however, it will be quite helpful if the question being asked is described in detail. In relation to the type of questions that might be asked by educational planners, the following will appear highly simplified, and rightly so: the problem was conceived solely for the purposes of this explanation.

effect on projected enrollments of some policy change(s), change(s) in the environment exogenous to the educational system, student behavior change(s) or resource allocation change(s)?" In the present form of the model, these changes would be input in terms of changes in the quantities of first-time freshmen, or upper-level entrants for a given year or years; or in terms of changes in the transition proportions for a given year or years. This change procedure is such that only the values of a single year's projections can be changed in a given iteration — although the use of the dynamic updating procedure allows for changing overall trends by insertion of only one years' changed values.

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One of the great concerns of our hypothetical planner (the "user" heretofore referred to) may be the interface between the public and private sectors of the educational system. He has heard rumored that another year or two will see a very significant tuition increase for undergraduate students at private four-year colleges in the state, and it is his feeling that many of the students who enter the state higher educational system at other than the freshman level who would ordinarily have come into the private sector will enter the public sector instead. Generally speaking, he wishes to see the impact on higher educational enrollments in both sectors subsequent to this tuition increase. It might be noted that although this is a hypothetical problem, real problems of this nature have been forecasted.

It is the analyst's option that only full-time rather than part-time students will be affected by the increased tuition; in addition, that male students rather than females will be affected by it; and, finally, that the effects will be such that in the year following the tuition increase, the tuition will be brought back to its former level, i.e., that the increase in tuition will be an "episodic event," as will be the influx of students from the private to the public sector. Given the size of the rumored increase, the planner expects that in the year of the tuition change (most probably 1970), upper-level entrants into the private colleges' four-year undergraduate programs will be fewer by ten percent than the number projected for that year.

The planner has now defined his question in operational terms with regard to the inputs required to ask it of the computer model. Returning to the original projection of upper-level entrants into the four-year private schools (undergraduate level) he finds that the former was 29,996, ten percent of which is approximately 3,000.

In answer to the question regarding "year of the change," the planner responds 1970 — the year in which he expects the tuition increase. After the model reminds the user of the codes (and identifying characteristics) of the variables available for change, of which there are three, he is asked to punch the code number of that variable in which changes will be made — in this case upper-level entrants, code 3. Referring back to the major classification scheme (always present for any block of output) he determines that four-year public school students at the undergraduate level always appear in the fifth column of printout — thus making the coded classification of the latter students "5". The categories of characteristics with which the planner is most concerned are "male," "full-time," and "resides in U.S. other than New York State." The coding scheme for categories of characteristics has a one-to-one correspondence with the order in which they are printed: since the order is male, female, full-time, part-time, resides in U.S. other than N.Y., and so forth, changes must be made in 3 categories 1, 3, and 5. (It must be noted that for simplicity, it has been assumed in this example that an entrant into the educational system at some level above freshman must reside outside New York State. Obviously, such is not necessarily the case — a New York resident may start college in another state and during some later year transfer back into his home-state's educational system.) Of course, changes might have been made in all nine categories if both males and females, both full and part-time students, and students from all geographic origins were felt to be affected by the postulated tuition change. In this case, the input would have been 5,9,1,2,3,4,5,6,7,8,9.

The planner is then instructed to input the increases or decreases corresponding to the categories he has specified. For the case in point, the planner is adding three-thousand male, full-time, non-New York residents, i.e., 3,000 male, 3,000 full-time, and 3,000 non-New York, in terms of the structure of the model. (The word DELETED is printed by the time-sharing system if the user indicates that he has made a mistake by punching a certain combination of keys. Since it was not desired that 30,003 full-time students be added, the entire line of input was erased by punching that combination.)

The next question asked by the computer is whether other changes are going to be made on the same variable, the latter currently being upper-level entrants. The planner has yet to decrease the four-year private college (undergraduate) upper-level entrants by 3,000, so he still desires to make changes in variable 3. He thus types YES to the question SAME VARIABLE? Again referring to the major classification scheme, the code of the four-year private undergraduates is 7. The number of changes to be made is 3, and the codes of the categories (element codes) are the same since the simulated students will not change their sex or geographic origin is going to public rather than to private schools. Another assumption being made is that the private sector is being depleted only in terms of full-time students. The input is thus of the form 7,3,1,3,5, and, again, the changes (now decreases) are -3,000, -3,000, -3,000. No more changes are to be made in upper-level entrants, and, in fact, no other variables are to be changed. As can be seen in the sample output, a "4" is punched by the user in answer to the question concerning the code number of the next variable to be changed. Finally, since the event whose effects are to be analyzed is assumed episodic, the user commands that the episodic updating procedure be utilized for the next set of projections by typing "2" when asked for orders.

At this point, the entire printout cycle begins anew. Since it was assumed that the number of entering first-time freshmen would not be affected by the tuition change, there is no need to waste time printing first-time freshmen again; and the response to the printout query is NO. It is, however, expected that the total student population will change, if not in numbers, at least in distribution of numbers: thus it _is_ printed. Setting aside the printout of total students for a moment, it will be noted that a printout of entering students was called for: the purpose here was to indicate the effect of the episodic updating procedure. As will be noted, only two numbers have changed between 1970 and 1975; and no printout is available for the years prior to the change. In the case of the latter, since the future does not affect the past, there will never be any effect in those years prior to the year in which a change has been instituted: thus these prior years are not printed. In the instance of the effects of the episodic update, by definition, the loss of 3,000 students by the private sector in 1970 (from 29,996 to 26,996) gained by the public sector in that year (from

21214 to 24214) is a one-time affair with no after effects on the future viz., 1971 projections of upper-level entrants, and thus the latter remain as they were in their previous printout.

Returning now to the output of total students (again, printed only for those years for which the change may have effect), careful comparison must be made with the original total student printout. It is the planner himself who can best judge the results, and detailed analysis of them will not be attempted here. It may be well to note, however, some general points of comparison. First, of course, is the fact that the 1970 projections differ only in that four-year public undergraduate enrollments have increased by 3,000 (from 171,706 to 174,706) and four-year private undergraduate enrollments have decreased by a like number (from 248,454 to 245,454). Second, that the aggregates (the second block of printout) have been updated accordingly. Third, that in 1971 the distribution of enrollments is quite different from what it was before, and that the 1971 grand total is lower in the new projections due to higher attrition and/or higher percentages obtaining degrees in the public sector. Fourth, that the influx of students in the public sector, and "outflux" of students in the private sector add an impulse and cause a gap, respectively, in the enrollments of the graduate schools for which the undergraduate schools are a primary source; and finally, that the perturbation dies out over time as the equilibrium of the system is reestablished.

The next question that arises is that of change in the student population with regard to categories of characteristics by which they are described. After answering in the affirmative the question by the computer of whether or not to print this breakdown of the population, the user is instructed that the earliest year available for printout is 1970 (the year in which the change was instituted). Briefly, the two years desired, 1970 and 1975, are printed. As expected the four-year public undergraduates show an increase in the number of male students in 1970 (81,176 to 84,176) of 3,000, as do full-time and non-New York residents. The four-year private undergraduates have 3,000 fewer males, and so forth. By 1975, the differences between the original projections and the new ones have become small, although the differences in the transition proportions between the public and private four-year schools and the two-year schools (some flow from four-year to two-year is indicated by the historical data) have changed the sex, status, and geographic origin distributions in the two-year public schools to an extent.

It is analysis of the transition matrices which gives exact information as to the changes seen in the projections of total students in the years subsequent to the year in which the changes in variable values were made. While the thrust of the possible analysis will not be discussed, the approach would, again, be that of comparison of the present results with those of the prior iteration. Thus, for example, the reason that the 1971 figure for total two-year public school (career) students went from 90,918 in the first iteration to 90,970 in the second is seen in the first column of the 1970 (representing 1970-1971) transition matrix: when compared to that obtained for the first iteration, this change is small, but will be used for expository purposes. In the latter, the number of students moving from four-year public undergraduate to two-year public (career) for the following year was 5,134; from four-year private schools there were 3,123. Since it was assumed that 1970 would see 3,000 fewer four-year private-school undergraduates, it is to be expected that there would be fewer of the latter moving to the two-year public (career program) for 1971: such was the case, and the second iteration result was that only 3,086 four-year private undergraduates switched to two-year public schools (career program) for 1971 — a decrease of 37 students. On the other hand, with 3,000 additional undergraduates in the four-year public schools, it was to be expected that there would be a greater number of the latter moving to the two-year public schools (career program) for 1971: such, too, was the case, and the second iteration resulted in 5,224 students making this move — an increase over the original 5,134 of 90 students. The net gain for the two-year public school career program was thus 90-37 or 53 students — the difference (within the limits of round-off error) between 90,918 and 90,970.

It might be well to note at this point that the detailed explanation of an analytic process is generally longer than the process itself. As stated previously, the model under consideration is a prototype: experience with it will indicate methods by which the analytic procedures required for its use can be simplified — perhaps by different formatting of output, or different arrangement of same.

The program has at this point reached the end of the second iteration. The number of iterations is not constrained by the program _per se_, but rather by considerations of the planners' time and costs. If the word NO were answered in response to IS ANOTHER SET OF PROJECTIONS DESIRED? the program would end. The word YES has been entered, however, and it may be assumed that another set of assumptions concerning the future is about to be implemented in the simulated educational system.

F. Concerning Predictive Accuracy

As was stated in the brief introduction to this explanatory run, the results given are not meant to represent New York's higher educational enrollments over the coming year.

While the process performed by the model to age student populations appeals to our sensibilities as truly representative of that which occurs in an educational system, by no means may we fairly evaluate its predictive accuracy as yet. In addition to the aging process, there is a second main component to the student population projections — development of the projected transition matrices and matrices of first-time freshmen and upper-level entrants. As has been stated, the latter "development" is accomplished through the use of multiple regression models which relate some set of independent variables to the (dependent) variables under study through an equation or set of equations. The dependent variables are well defined in the prototype under consideration; they are the elements of the three types of matrices just mentioned. The independent variables are not so well defined — in fact they are undefined until research has been undertaken to discover those variables which appear to be related to the dependent variables. Moreover, the nature of this relationship must be determined so that the resulting regression equation will mirror the relationship to the real world.

Such research has not been undertaken in the present work. Had it been, there might have been reference to such independent variables as Gross National Product, median yearly income in the State, and population growth; and allusions to different alternative functional forms relating these variables to the dependent variables in question. Thus, for example, a viable regression model for projection of first-time freshmen might be a function of time, of the logarithm of G.N.P., the square-root of the population of New York, and the reciprocal of military spending. Obviously, the number of possible regression models is limitless: the problem is finding one that fits the historical data to the greatest extent possible without "overdetermination" — that is, the use of too many independent variables, with consequent obviating of statistical validation. The model thus should not be evaluated on the basis of the numbers it has produced to date. As has been stated in a previous section, the regression model used was that of a straight line — a slope and an intercept — based entirely on the passage of time. While time will surely prove to be an important independent variable, possibly the most important, it may be found that the introduction of other independent variables into the regression model will make the regression equations fit more closely the historical data, and possibly improve the projections.*

That the aforementioned research was not done was neither an oversight nor an error. The model under consideration is only a prototype: it possesses the basic wherewithal for projection of higher educational enrollments. Our basic purpose thus becomes one of evaluating its operating characteristics in an actual planning environment, and its capability of fulfilling some of the needs of the planners themselves so that they can be better equipped for the performance of their work. Once it has been decided that the model can, in fact, be useful, then it will be more appropriate to conduct further research into the actual structure of the projection relationships.

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*It was recognized that a large degree of auto-correlation may, and quite possibly does, exist between the assumed dependent variates. As stated, however, the emphasis at this stage of development has been directed toward an assessment of the overall viability and "usefulness" of the model in a planning environment.

APPENDIX 2.A

SAMPLE OUTPUT

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NØ. ØF YRS. TØ PRØJECT?8

PRINT FIRST TIME FRESHMEN?(YES ØR NØ)?YES

                     TWØ-YEAR                               FØUR-YEAR
           PUBLIC                PRIVATE              PUBLIC                PRIVATE
YEAR     CAR      TRANS       CAR      TRANS      UND        GRAD      UND        GRAD
1965   19838.   19838.      1668.     1668.    33052.         0.    49827.         0.
1966   22300.   22300.      1715.     1715.    31700.         0.    49500.         0.
1967   25100.   25100.      1760.     1760.    34600.         0.    51900.         0.
1968   27675.   27675.      1806.     1806.    34665.         0.    52482.         0.
1969   30306.   30306.      1852.     1852.    35439.         0.    53518.         0.
1970   32937.   32937.      1898.     1898.    36213.         0.    54555.         0.
1971   35568.   35568.      1944.     1944.    36987.         0.    55591.         0.
1972   38199.   38199.      1990.     1990.    37761.         0.    56628.         0.
1973   40830.   40830.      2036.     2036.    38535.         0.    57664.         0.
1974   43461.   43461.      2082.     2082.    39309.         0.    58701.         0.
1975   46092.   46092.      2128.     2128.    40083.         0.    59737.         0.


YEAR   PUB-2YR    PRI-2YR    PUB-4YR    PRI-4YR    TØT-2YR    TØT-4YR    GRAND TØT
1965    39676.      3336.     33052.     49827.     43012.     82879.    125891.
1966    44600.      3430.     31700.     49500.     48030.     81200.    129230.
1967    50200.      3520.     34600.     51900.     53720.     86500.    140220.
1968    55349.      3613.     34665.     52482.     58962.     87147.    146109.
1969    60611.      3705.     35439.     53518.     64316.     88958.    153274.
1970    65873.      3797.     36213.     54555.     69670.     90768.    160438.
1971    71135.      3889.     36987.     55591.     75024.     92579.    167603.
1972    76397.      3981.     37761.     56628.     80378.     94389.    174767.
1973    81659.      4073.     38535.     57664.     85732.     96200.    181932.
1974    86921.      4165.     39309.     58701.     91086.     98010.    189096.
1975    92183.      4257.     40083.     59737.     96440.     99821.    196261.


PRINT TØTAL STUDENTS?YES
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                   TWO-YEAR                             FOUR-YEAR
          PUBLIC                PRIVATE            PUBLIC            PRIVATE
YEAR     CAR     TRANS      CAR     TRANS      UND      GRAD      UND     GRAD
1965   48977.   48978.    3590.     3590.  157944.   23132.  224803.   57899.
1966   54269.   54346.    3653.     3623.  150971.   36753.  218322.   75990.
1967   58096.   58276.    3701.     3704.  158564.   40703.  224684.   80002.
1968   66593.   67616.    3789.     3794.  159557.   48683.  232468.   88567.
1969   74192.   74983.    3900.     3892.  165183.   55108.  239382.   95511.
1970   82296.   82947.    4012.     3999.  171706.   60987.  248454.  101555.
1971   90918.   91332.    4128.     4110.  178752.   66402.  258991.  107025.
1972  100030.  100065.    4247.     4226.  186042.   71416.  270499.  112086.
1973  109612.  109095.    4370.     4344.  193375.   76073.  282636.  116813.
1974  119647.  118382.    4496.     4463.  200618.   80408.  295169.  121232.
1975  130127.  127887.    4624.     4583.  207683.   84446.  307946.  125349.

YEAR  PUB-2YR  PRI-2YR  PUB-4YR  PRI-4YR  TOT-2YR  TOT-4YR  GRAND TOT
1965   97955.    7180.  181076.  282702.  105135.  46[illegible]778.  558913.
1966  108615.    7276.  187724.  294313.  115891.  482036.  597928.
1967  116372.    7405.  199267.  304686.  123777.  503954.  627731.
1968  134209.    7583.  208239.  321034.  141792.  529274.  671066.
1969  149175.    7792.  220291.  334893.  156967.  555184.  712151.
1970  165243.    8010.  232693.  350009.  173254.  582702.  755956.
1971  182250.    8238.  245155.  366016.  190488.  611170.  801658.
1972  200095.    8473.  257457.  382586.  208568.  640043.  848611.
1973  218707.    8714.  269448.  399449.  227421.  668897.  896318.
1974  238029.    8959.  281025.  416402.  246988.  697427.  944415.
1975  258014.    9207.  292129.  433295.  267222.  725424.  992646.
PRINT UPPERCLASS ENTRANTS?YES

                   TWO-YEAR                             FOUR-YEAR
          PUBLIC                PRIVATE            PUBLIC            PRIVATE
YEAR     CAR     TRANS      CAR     TRANS      UND      GRAD      UND     GRAD
1965     952.    1020.     214.      220.    6276.    3140.    8092.    4263.
1966     970.    1105.     234.      190.    7376.   10412.   10945.   13188.
1967    1062.    1396.     195.      232.   12521.    5978.   17072.    8215.
1968    1105.    1550.     195.      226.   14969.    9348.   21015.   12507.
1969    1160.    1738.     186.      232.   18092.   10767.   25506.   14483.
1970    1215.    1926.     176.      238.   21214.   12186.   29996.   16459.
1971    1270.    2114.     167.      244.   24337.   13605.   34486.   18435.
1972    1325.    2302.     157.      250.   27459.   15024.   38976.   20411.
1973    1380.    2490.     148.      256.   30582.   16443.   43466.   22387.
1974    1435.    2678.     138.      262.   33704.   17862.   47956.   24363.
1975    1490.    2866.     129.      268.   36827.   19281.   52446.   26339.
```

```
PRINT STUDENTS BY CHARACTERISTIC?YES

HØW MANY YEARS ØF ØUTPUT, AND WHICH YEARS
(EARLIEST YEAR CAN BE 1965)?3,1967,1970,1975

        READING DØWN THE ØRDER IS:
        MALE,FEMALE,FULL-TIME,PART-TIME,U.S. ØTHER THAN
        NEW YØRK STATE,FØREIGN,RESIDES IN CØUNTY ØF SCHØØL,
        RESIDES IN ECØ. AREA (EXCL. CØUNTY) ØF SCHØØL,
        RESIDES IN NEW YØRK BUT NØT ECØ. AREA ØF SCHØØL.


                                 YEAR 1967

                TWØ-YEAR                                  FØUR-YEAR
       PUBLIC                PRIVATE            PUBLIC                 PRIVATE
  CAR       TRANS          CAR      TRANS          UND      GRAD          UND      GRAD
34478.     34357.        1887.      1916.       84808.    22364.     141676.    52240.
23617.     23920.        1814.      1788.       73756.    18339.      83008.    27762.
31970.     34167.        2969.      2963.      117065.    16872.     181038.    42527.
26125.     24109.         732.       741.       41499.    23832.      43647.    37475.
 2609.      3556.        1280.      1216.        5030.     1562.      54874.    10512.
  361.       454.          65.        65.         933.      302.       5864.     1607.
35971.     36015.        1009.      1120.      119558.    30216.     114211.    48290.
 7095.      6457.         263.       261.       10480.     2562.       8814.     3726.
11116.     10877.        1085.      1042.       22525.     5946.      40971.    15863.


                                 YEAR 1970

                TWØ-YEAR                                  FØUR-YEAR
       PUBLIC                PRIVATE            PUBLIC                 PRIVATE
  CAR       TRANS          CAR      TRANS          UND      GRAD          UND      GRAD
44360.     45445.        2068.      2082.       81176.    33314.     154512.    63874.
37936.     37503.        1944.      1917.       90530.    27673.      93942.    37681.
47212.     51343.        3137.      3131.      128439.    28821.     199284.    58816.
35086.     31607.         877.       867.       43267.    32166.      49170.    42740.
 4433.      6996.        1340.      1286.        6470.     3177.      59588.    13984.
  439.       728.          66.        68.         898.      528.       6815.     2038.
49206.     48844.        1146.      1224.      127790.    43965.     127471.    61165.
 9575.      8441.         302.       255.       11214.     3764.       9672.     4751.
15440.     15335.        1141.      1102.       25020.     9091.      45363.    19627.
```

```
                                            YEAR 1975

                     TWO-YEAR                                            FOUR-YEAR
           PUBLIC                   PRIVATE                PUBLIC                     PRIVATE
     CAR        TRANS          CAR        TRANS          UND          GRAD           UND           GRAD
   63606.      65495.         2387.       2389.        82213.       44221.        187044.        76921.
   66522.      62392.         2237.       2193.       125470.       40225.        120901.        48429.
   77263.      82127.         3452.       3452.       158035.       40352.        245330.        68523.
   52873.      45766.         1178.       1131.        49649.       44093.         62617.        56827.
    8379.      12985.         1487.       1449.         8242.        4632.         72400.        16391.
     619.       1275.           69.         74.          735.         742.          8957.         2571.
   75001.      72502.         1369.       1394.       153722.       60148.        159336.        75833.
   14488.      12086.          371.        259.        13271.        5147.         11693.         5731.
   24130.      23535.         1271.       1238.        30803.       12676.         56424.        24833.
PRINT TRANSITION MATRICES?YES

HOW MANY YEARS OF OUTPUT, AND WHICH YEARS
(EARLIEST YEAR CAN BE 1965)?3,1968,1970,1975

FIRST EIGHT ROW HEADINGS SAME AS FIRST EIGHT
COLUMN HEADINGS.  LAST TWO COLUMNS ARE ACADEMIC
ATTRITION AND 'LEFT WITH DEGREE', RESPECTIVELY


                                            YEAR 1968

   2PC       2PT        2PRC      2PRT      4PU       4PG      4PRU      4PRG       OW        DEG

 22597.    3507.       133.      133.      999.        0.      564.        0.   32651.     6009.
 13304.   18909.       137.      137.     5322.        0.      747.        0.   28226.      834.
    15.      95.       955.      409.       25.        0.      115.        0.    1511.      664.
     8.       8.       637.      842.       75.        0.      532.        0.    1524.       68.
  4436.    7840.         0.      106.    99989.     6382.     3670.     6595.   15748.    14791.
     0.       0.         0.        0.        0.    33467.        0.      227.    5846.     9142.
  2367.   12582.         0.      180.     5243.     2996.154729.     12956.   19727.    21689.
     0.       0.         0.        0.        0.     1496.        0.    61249.    9156.    16666.


                                            YEAR 1970

   2PC       2PT        2PRC      2PRT      4PU       4PG      4PRU      4PRG       OW        DEG

 28584.    4005.       165.      165.     1234.        0.     1092.        0.   39609.     7442.
 17215.   23047.       169.      169.     6446.        0.     1296.        0.   33557.     1048.
    16.     100.      1011.      433.       31.        0.      122.        0.    1595.      703.
     8.       8.       672.      883.       83.        0.      561.        0.    1707.       72.
  5134.    8454.         0.       80.104168.     7212.     4293.     5410.   18493.    17462.
     0.       0.         0.        0.        0.    40278.        0.      407.    8056.    12246.
  3123.   18037.         0.      187.     5466.     3592.161550.     12571.   21082.    22847.
     0.       0.         0.        0.        0.     1715.        0.    69202.   10910.    19728.
```

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                                          YEAR 1975

   2PC     2PT      2PRC     2PRT    4PU      4PG     4PRU     4PRG      ØW      DEG

  47800.  5032.     260.     260.   1952.      0.    3288.       0.  59702.  11833.
  30087. 34943.     266.     266.   9614.      0.    3503.       0.  47492.   1716.
     18.   116.    1165.     499.     47.      0.     140.       0.   1827.    811.
      9.     9.     770.    1017.    106.      0.     643.       0.   1945.     82.
   7300. 10277.       0.       0.115606.   9761.    6230.    5676.  27039.  25793.
      0.     0.       0.       0.      0.  50067.       0.     986.  13689.  19703.
   5563. 35427.       0.     219.   6383.   5563.189354.   11946.  26126.  27366.
      0.     0.       0.       0.      0.   2117.       0.   82239.  14737.  26256.
IS ANØTHER SET ØF PRØJECTIØNS DESIRED?YES

FØR WHAT YEAR ARE CHANGES IN PRØJECTED VALUES TØ BE MADE?1970

         1.   TRANSITIØN MATRIX(RØW,CØLUMN)
         2.   FIRST-TIME-FRESHMEN(SCHØØL/STATUS,CHARACTERISTIC)
         3.   UPPERCLASS ENTRANTS(SCHØØL/STATUS,CHARACTERISTIC)

PUNCH CØDE NUMBER ØF VARIABLE TØ
BE CHANGED.  PUNCH 4 IF NØ MØRE CHANGES TØ BE MADE.?3

PUNCH CØDED CLASSIF., NØ. ØF CHANGES,ELEMENT CØDES?5,3,1,3,5

PUNCH THE  3 INCREASE(S),DECREASE(S)?3000,30003 DELETED
3000,3000,3000

SAME VARIABLE?YES

PUNCH CØDED CLASSIF., NØ. ØF CHANGES,ELEMENT CØDES?7,3,1,3,5

PUNCH THE  3 INCREASE(S),DECREASE(S)?-3000,-3000,-3000

SAME VARIABLE?NØ

PUNCH CØDE NUMBER ØF VARIABLE TØ
BE CHANGED.  PUNCH 4 IF NØ MØRE CHANGES TØ BE MADE.?4

INPUT CØDE NØ. ØF METHØD FØR NEXT PRØJECTIØNS
PUNCH 1 IF DYNAMIC UPDATE, 2 IF EPISØDIC UPDATE
PUNCH 3 TØ END THE RUN.  ØRDERS?2

PRINT FIRST TIME FRESHMEN?(YES ØR NØ)?NØ

PRINT TØTAL STUDENTS?YES
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                TWO-YEAR                                     FOUR-YEAR
          PUBLIC               PRIVATE             PUBLIC              PRIVATE
YEAR    CAR     TRANS      CAR      TRANS      UND     GRAD      UND     GRAD
1970   82296.   82947.    4012.     3999.  174706.   60987.  245454.  101555.
1971   90970.   91262.    4128.     4110.  180507.   66485.  257115.  106985.
1972  100062.   99981.    4247.     4225.  187043.   71515.  269339.  112032.
1973  109620.  109018.    4370.     4343.  193931.   76161.  281924.  116758.
1974  119640.  118318.    4496.     4462.  200918.   80474.  294736.  121183.
1975  130113.  127838.    4624.     4582.  207839.   84492.  307683.  125308.

YEAR   PUB-2YR   PRI-2YR   PUB-4YR   PRI-4YR   TOT-2YR   TOT-4YR   GRAND TOT
1970   165243.     8011.   235693.   347009.   173254.   582702.   755956.
1971   182232.     8237.   246991.   364100.   190469.   611092.   801561.
1972   200043.     8472.   258558.   381370.   208515.   639929.   848444.
1973   218638.     8712.   270092.   398682.   227350.   668774.   896125.
1974   237958.     8958.   281392.   415919.   246916.   697311.   944226.
1975   257951.     9206.   292330.   432992.   267157.   725322.   992479.
PRINT UPPERCLASS ENTRANTS?YES

                TWO-YEAR                                     FOUR-YEAR
          PUBLIC               PRIVATE             PUBLIC              PRIVATE
YEAR    CAR      TRANS      CAR      TRANS      UND     GRAD      UND     GRAD
1970    1215.    1926.     176.      238.    24214.   12186.   26996.   16459.
1971    1270.    2114.     167.      244.    24337.   13605.   34486.   18435.
1972    1325.    2302.     157.      250.    27459.   15024.   38976.   20411.
1973    1380.    2490.     148.      256.    30582.   16443.   43466.   22387.
1974    1435.    2678.     138.      262.    33704.   17862.   47956.   24363.
1975    1490.    2866.     129.      268.    36827.   19281.   52446.   26339.
PRINT STUDENTS BY CHARACTERISTIC?YES

HOW MANY YEARS OF OUTPUT, AND WHICH YEARS
(EARLIEST YEAR CAN BE 1970)?2,1970,1975

            READING DOWN THE ORDER IS:
            MALE,FEMALE,FULL-TIME,PART-TIME,U.S. OTHER THAN
            NEW YORK STATE,FOREIGN,RESIDES IN COUNTY OF SCHOOL,
            RESIDES IN ECO. AREA (EXCL. COUNTY) OF SCHOOL,
            RESIDES IN NEW YORK BUT NOT ECO. AREA OF SCHOOL.
```

```
                                      YEAR 1970

                   TWØ-YEAR                                   FØUR-YEAR
           PUBLIC               PRIVATE               PUBLIC              PRIVATE
     CAR      TRANS        CAR      TRANS         UND      GRAD        UND      GRAD
  44360.     45445.      2068.      2082.      84176.    33314.    151512.    63874.
  37936.     37502.      1944.      1917.      90530.    27673.     93942.    37681.
  47212.     51343.      3137.      3132.     131439.    28821.    196284.    58816.
  35086.     31607.       877.       867.      43267.    32166.     49170.    42739.
   4433.      6996.      1340.      1286.       9470.     3177.     56588.    13984.
    439.       728.        66.        68.        898.      528.      6815.     2038.
  49206.     48844.      1146.      1225.     127790.    43965.    127471.    61165.
   9575.      8441.       302.       255.      11214.     3764.      9672.     4751.
  15440.     15335.      1141.      1103.      25020.     9091.     45363.    19627.


                                      YEAR 1975

                   TWØ-YEAR                                   FØUR-YEAR
           PUBLIC               PRIVATE               PUBLIC              PRIVATE
     CAR      TRANS        CAR      TRANS         UND      GRAD        UND      GRAD
  63591.     65446.      2387.      2389.      82369.    44267.    186782.    76880.
  66522.     62392.      2237.      2193.     125470.    40225.    120901.    48429.
  77248.     82078.      3451.      3452.     158191.    40398.    245067.    68482.
  52873.     45766.      1178.      1131.      49649.    44093.     62617.    56827.
   8365.     12936.      1487.      1449.       8398.     4678.     72138.    16350.
    619.      1275.        69.        74.        735.      742.      8957.     2571.
  75001.     72502.      1369.      1394.     153722.    60148.    159336.    75832.
  14488.     12086.       371.       259.      13271.     5147.     11693.     5731.
  24130.     23535.      1271.      1238.      30803.    12676.     56424.    24833.
PRINT TRANSITIØN MATRICES?YES

HØW MANY YEARS ØF ØUTPUT, AND WHICH YEARS
(EARLIEST YEAR CAN BE 1970)?2,1970,1975

FIRST EIGHT RØW HEADINGS SAME AS FIRST EIGHT
CØLUMN HEADINGS.  LAST TWØ CØLUMNS ARE ACADEMIC
ATTRITIØN AND 'LEFT WITH DEGREE', RESPECTIVELY



                                      YEAR 1970

   2PC     2PT      2PRC      2PRT      4PU      4PG     4PRU      4PRG       ØW      DEG

 28584.   4005.     165.      165.    1234.       0.    1092.        0.  39609.   7442.
 17215.  23047.     169.      169.    6446.       0.    1296.        0.  33557.   1048.
    16.    100.    1011.      433.      31.       0.     122.        0.   1595.    703.
     8.      8.     672.      888.      83.       0.     561.        0.   1707.     72.
  5224.   8601.       0.       82.105988.    7338.    4368.     6522.  13816.  17768.
     0.      0.       0.        0.       0.  40278.       0.      407.   8056.  12246.
  3086.  17819.       0.      185.    5400.   3548.159599.    12419.  20827.  22571.
     0.      0.       0.        0.       0.   1715.       0.    59202.  10910.  19728.
```

```
                                   YEAR 1975

  2PC   2PT      2PRC   2PRT   4PU    4PG   4PRU   4PRG    0W     DEG

 47795.  5031.   260.   260.  1952.     0.  3288.     0. 59696. 11832
 30076. 34929.   266.   266.  9610.     0.  3502.     0. 47474.  1715
    18.   116.  1165.   499.    47.     0.   140.     0.  1827.   811
     9.     9.   770.  1017.   106.     0.   643.     0.  1945.    82
  7305. 10284.     0.     0.115693.  9768.  6235.  5681. 27060. 25813
     0.     0.     0.     0.     0. 50095.     0.   986. 13697. 19714
  5558. 35397.     0.   219.  6378.  5558.189193. 11936. 26103. 27343
     0.     0.     0.     0.     0.  2117.     0. 82212. 14732. 26247
IS ANOTHER SET OF PROJECTIONS DESIRED?YES
```

SECTION III

CASE STUDIES

A. Introduction

The case studies reported in this section represent an attempt to implement the simulation model in three different yet collectively representative educational systems. Consequently, these studies represent a set of real world experiments designed to assess both the conceptual validity and operational feasibility of utilizing the simulation model for planning purposes. The purposes of these cases were then twofold: (1) to assess the relationships between the existing higher education data bases and the input requirements of the simulation model; and (2) to evaluate the usefulness of the prototype model to educational planners at the institution level. A major concern of the data requirements was with the potential disparity between the content, disaggregation, accuracy, reliability, and level of precision of the information required and that found in representative sources.

Two alternative (but not entirely mutually exclusive) procedures for amassing the required input information were attempted:

1. asking for subjective estimates from knowledgeable persons at institutions of higher learning and combining these

estimates with existing aggregate data; and

2. statistically sampling unit records at representative institutions.

The four institutions chosen for this initial experiment compose a representative cross-section of the higher education system in New York State.

The City University of New York (CUNY) is a tuition free institution which offers approved graduate and undergraduate programs in nine four year senior colleges and six two year community colleges in New York City. 1967 enrollment has expanded to 144,000 students, of which 64,000 have been full-time, matriculated students.

Rensselaer Polytechnic Institute (RPI) is a private non-sectarian, technological university in Troy, New York. Rensselaer emphasizes a technological education in Engineering and Science on both the undergraduate and graduate levels. Architecture, Humanities and Social Sciences, and Management curricula are also offered on the same levels. At the present time, Rensselaer has a coeducational environment of approximately 3,550 undergraduate and 1,100 graduate students.

Hudson Valley Community College (HVCC) is one of thirty-one two-year community colleges locally sponsored under the program of the State University of New York. It has a current enrollment of 3,833 full time students at its campus in Troy, New York. Most of the students are distributed among six academic divisions which offer associate degrees.

Syracuse University in Syracuse, New York is a semi-private educational institution with a total student enrollment of nearly 23,000 in the Spring of 1968. Syracuse has 15 undergraduate schools which include the State University College of Forestry and Utica College in Utica, New York. The graduate school offers advanced studies in all undergraduate areas as well as in architecture and social work.

In the case studies to follow, the above alternative procedures will be seen to have been implemented in distinct but complementary ways. By far the greatest amount of effort was devoted to the evaluation of the CUNY data base: it was felt that not only would CUNY yield many difficult problems relating to data acquisition for the prototype, but that it was, as a system of colleges, an analogue to the statewide educational system. With the latter thought in mind, it was decided to evaluate both methods 1 and 2 above at CUNY, although, as will be noted, actual unit record collection was not performed as a result of this evaluation.

At Rensselaer Polytechnic Institute a data set fulfilling the requirements of the prototype was collected through the sampling of individual student records. Subjective estimates of knowledgeable individuals were combined with aggregate data on file in the registrar's office for the development of a data set at Hudson Valley Community College.

While not mentioned in the cases, an advanced management information system in use at Syracuse University was studied to determine whether the form and content of the data which could be retrieved would meet the input needs of the prototype. The study showed that the information form and content of this system while quite advanced were not amenable to analysis by the simulation model. As a result, Syracuse University was not included as a formal case study.

The selection of the above institutions as representative was made with several practical considerations in mind, including the minimization of travelling and living expenses associated with the research activities and the administrative cooperation necessary before the data collection could be carried out. Thus, Rensselaer was chosen as the institution at which to conduct the unit record sampling since it was known that such a process would be time consuming and much in the way of travelling and living expenses could be eliminated. Selection of a small college for the collection of subjective estimates would enhance the probability that they could be obtained in the quantities required and time available. Hudson Valley Community College proved to be eminently suitable for our purposes.

Syracuse University had been considered for study of the electronic data processing information system in collecting and storing data as it was commonly felt to have the most highly automated system. It may thus be seen that the initial sample of schools felt to be "representative" involved a large public university system, CUNY; a large private school, Syracuse University; a small private 4 year school, Rensselaer Polytechnic Institute; and a small public school, Hudson Valley Community College.

The ensuing part of this section involves three cases; those of CUNY, RPI, and HVCC, in that order. Following the three case discussions, conclusions on viable approaches to data accumulation for the prototype will be drawn with an eye toward information content desired, and data availability and form.

B. Case Study: City University of New York

The City University of New York was formed in 1961 from the autonomous colleges previously associated through the municipal college system. Student data systems at these colleges were as different as the schools themselves at that time. These long standing information systems remained unchanged with the consolidation into the City University. Since that time, some movement has been made toward a more uniform data set, and recent developments have seen the schools agreeing on some common definitions of academic level and status classifications, although all historical data are locked into the previously established categories.

The forces affecting enrollments of the City University of New York offer great substance for a simulation model and great opportunity for its use. The policy of the City University is to offer regular admission to qualified residents of New York City and special admissions from approved programs to a number of disadvantaged graduates of City high schools. The university is tuition free and relies heavily on the City and State for support. CUNY is composed of nine four year senior colleges, and six two year community colleges. Student transfers, both between the two types of colleges and among colleges of the same respective type are frequent. The university is in a period of expansion, especially in its community colleges and special programs. While each college maintains a degree of autonomy in determining its own destination, university wide policies are set by the Board of Higher Education. The Dean of the Master Plan is responsible for anticipating and planning for university growth.

The areas of model building explored and evaluated at CUNY include:

1. determination of major classification scheme and categories of characteristics;
2. methods of determining required parameter values;
3. methods of updating the historical data as new yearly sets become available, and of collecting the new sets;
4. implementation of special user features, such as real-time remote access to the model program, and allowance for changes in projected data according to subjective estimates.

For clarity of presentation, this section is divided into two major parts: the first deals with the potential of using individualized records to provide input to the simulation, and the second deals with a model whose results are a function of the aggregate data collected for it.

1. Feasibility of Unit Record Data

As previously discussed (and inherent in the structure of the model) the specific content (the classifications and characteristics into which students are grouped) are specified by users. To help determine the form of the desired output information, a preliminary meeting was held at the New York City Board of Higher Education Building on July 11, 1968, and attended by State officials, CUNY planners, representatives from the CUNY council of Registrars, and members of Rensselaer Research Corporation. Since this portion of the study would involve the examination of the permanent record systems of all schools within the CUNY system, this meeting also served to insure uniform prior knowledge and cooperation among all those concerned.

Problems were encountered in determining the content of the desired output. One difficulty arose primarily from the CUNY participants' initial lack of acquaintenance with the model's workings, in particular, its dependence upon historical data as the basis of projections. Output information objectives initially proposed by the university administrators and registrars were diverse. Many of the classification criteria suggested were not appropriate to this simulation or would not be present in any historical data. In short, many of the suggested objectives could not possibly have been met. The sum total of the "desired output" was actually a university wide data system. It was concluded that current projection objectives would be restricted to those classifications covered historically by the presently existing information system.

The CUNY information objectives are shown in Figure 9. Students were to be aged through the CUNY system according to their specific college and level at respective points in time. With nine senior college day programs, seven senior college night divisions, six community college transfers programs, and six community college career programs at distinct colleges (that is 28 "colleges" in all) and four levels for the senior colleges, with two levels for the community colleges, the total number of components in the major classification scheme would be 88. There would be six characteristics used as students descriptors: ethnic factor, student course load per semester, high school average at entrance, sex, status, and source of entrance to the CUNY system. For these six characteristics, there would be a total of 24 categories describing the students. In order to fulfill these information requirements, the set of data required from each student record would be that given in Figure 10.

Since unit record sampling needed to be carried out at all colleges, and since the model could incorporate only those groupings about which information could be gathered at all colleges, it was necessary to examine the file organization and permanent record form content at each school.

1. Major Classification Scheme

9 Senior Day Colleges
7 Senior Evening Colleges

Freshman
Sophomore
Junior
Senior

6 Community Colleges - Career Programs
6 Community Colleges - Transfer Programs

Freshman
Sophomore

2. Characteristics & Categories Within

Sex - M-F

High-School Average - 100-90,90-82,82-75,75-0

Ethnic Factor - Negro, Puerto Rican, Other

Source of Entrance - Regular NYC H.S. Senior, College Discovery, SEEK, Advance Standing from outside CUNY, other.

Course load/semester (units) - 2-4,5-7,8-10,11-13,14-16,17+

Status - Matriculated; Non-matriculated, Inactive honorable, Inactive dishonorable

FIGURE 9

INFORMATION OBJECTIVES OF A CUNY MODEL

(See Figure 2 page 21)

1.	Present Level	Freshman, Sophomore Junior, Senior, Graduated
2.	College Profile	College attended at beginning and end of each respective level, (Day-Eve. for Sr. Colleges and Career-Transfer for Community Colleges treated as separate schools)
3.	Credits Complete to Date	Exact Number
4.	Ethnic Factor	Negro, Puerto Rican, Other
5.	High School Average	100-90, 89-82, 81-75, 74-0
6.	Sex	Male, Female
7.	Year of Exit	Last two digits of year.
8.	Degrees Received in System	Associate, Bachelor
9.	Type Admission to CUNY System	Regular, NYC High School Senior, College Discovery, SEEK, Advance Standing from outside CUNY, other.
10.	Level of Entrance	Freshman, Sophomore, Junior, Senior
11.	Year of Entrance	Last two digits
12.	Entering Status	Matriculated, Non-matriculated

FIGURE 10

INDIVIDUAL STUDENT DATA REQUIRED

In sampling records of various years, representative records must be chosen from the files at hand. Consequently, organization of the registrars file systems largely determines the applicability of any sampling plan.

Furthermore, this data must be available from all colleges of the university system. Content of permanent record forms at CUNY, however, varies from school to school. The university does not have a homogeneous student information system. Differing information codes must be interpreted before the products of the different data systems can be combined into a single data base; and there is difficulty at CUNY in this respect due to the lack of common definitions of such terms as "sophomore" and "full-time" as well as the variations in form of data presentation on the records.

Registrars and assistant registrars from all institutions within the CUNY system were interviewed, and all record systems examined. The distinguishing features of the respective information systems were noted; and their effects on the intended sampling were anticipated. Since it was felt that difficulty might be encountered in obtaining certain narrowly defined cross classifications of students, the registrars were asked whether they would be able to supply us with "reasonable estimates" of these cross-classifications. Only in certain cases were the registrars querried able to provide this information.

A sampling plan was not devised in the case of the CUNY evaluative effort. Study of the individual data files of the separate institutions within CUNY indicated that there were great differences in the manner of reporting, as well as in the actual information reported on them. In addition, the organization of the files themselves were very different from institution to institution. For example, some information systems' records are split into two sections: active and inactive, and arranged alphabetically. On the other hand a record set might be divided into four active files, and five inactive files, with such titles as "bachelor dropouts", "associate dropouts", "non-matriculant dropouts", and so forth, some of which are arranged by date of admission or inactivation. Some of these schools are in periods of transition of their data files or have very recently completed such a change period. The resultant file variation over time would necessitate different plans for the sampling of different years' data even within a single school. Finally, York and Richmond Colleges, the youngest of the senior colleges, have file organizations lending themselves quite well to sampling; but by virtue of their newness, they have only one year of records which could be sampled.

Assuming that a working sampling plan could have been constructed to deal with the various file arrangements, the feasibility of data collection would have depended upon how well the data requirements stated in Figure 10 were met in the student record forms. Certain problems arose in this sphere. Thus, for example, ethnic factor is not available from any school's record form. The ethnic census of the university taken in September, 1967, provides only one year of data. In addition, its results were divided into the classifications of school and level but not into the more detailed sets described by the intersections of these categories such as School 3, junior level. Another factor difficult to obtain in general was that of high school average.

Particularizing, the record form of Staten Island Community College does not furnish a day-evening distinction. Other community colleges fail to differentiate between career and transfer programs students on their records. Some colleges do not distinguish between students admitted through the special programs, SEEK and College Discovery. Another important factor concerning incoming students is their previous college work; though such information is critical in the development of flow parameters (transition proportions), not all schools specify colleges of transferees' prior attendance.

2. CUNY: A Pilot Model Based on Aggregate Data and Subjective Estimates

A primary goal for the effort at City University was to implement the prototype model for CUNY's use based on parameters whose values could be developed within reasonable time and with data currently available. While individualized sampling was found infeasible, the central Office of Institutional Research (OIR) offered another approach to initial data collection. Aggregate enrollment and admissions figures are reported by the CUNY colleges to this office. While this form of data necessitated modification of original information objectives, these changes did not detract from the model's usefulness as a planning tool constructed for direct use by administrators. Development of the data set was monitored and guided by T. Edward Hollander, Dean of the CUNY Master Plan. Based upon broadly defined informational needs of the university planning function a feasible set of data requirements for the model was established. Similar to the individual colleges, the University OIR has varied its data collection forms considerably over time. An effective likeness among yearly enrollment, admission, and attrition reports goes back only to the 1965-1966 academic year. Therefore, only these "compatible" data were collected, and the prototype for CUNY projects on the basis of three years' historical data — 1965, 1966, and 1967.

The present emphasis of the planning in the City University is on the period ending in 1975. In its 1964 Master Plan, CUNY states a recently adopted goal of implementing a 100% admission policy by 1975 through expansion of programs at the senior and community colleges. According to this goal, the University will be able to offer some form of higher educational opportunity to all graduates of New York City High Schools. It must anticipate student demand, outside influences, and its own potential outlets for growth via expansion as well as new programs. Therefore, the study focused on the 1968-75 period.

In offering admission to a less and less competitive group of students, CUNY will try to channel a disproportionately large segment of the enrollment increment to its two-year community colleges. After graduating from one of the latter a student is guaranteed of junior level admission to the senior college of his choice. It is felt that this policy will provide a framework wherein the most talented and motivated students can go on through a four-year college experience while all high school graduates regardless of prior achievement are afforded the opportunity of doing some further work. The university administration is basically concerned with its community colleges, senior colleges, levels of academic attainment, and special programs as whole units.

The revised classification scheme chosen to best suit these concerns involves six components: community colleges as a group with two levels within them, and senior colleges as a group with four levels within them as shown in Figure 11

- community college
  - freshmen
  - senior
- senior college
  - freshman
  - sophomore
  - junior
  - senior

Figure 11

THE CUNY MAJOR CLASSIFICATION SCHEME

The associated form of the transition matrices for the CUNY model is shown in Figure 12.

Growth will heighten CUNY's problems of keeping aware of the representations of certain groups in each of the University's constituent parts. Although the 1967 ethnic census shows that CUNY has the largest minority group enrollment of any institution in the country, the percentage representations still do not reflect the ethnic distribution of the City's high school graduates. New programs to be initiated shortly will change the

		Community Colleges		Senior Colleges					
		Fr.	So.	Fr.	So.	Jr.	Sr.	ACAD ATT	Grad.
Community Colleges	Fr.	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
	So.	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
Senior Colleges	Fr.	.	.	.	.	.	.	.	.
	So.	.	.	.	.	.	.	.	.
	Jr.	.	.	.	.	.	.	.	.
	Sr.	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	a_{66}	a_{67}	a_{68}

FIGURE 12

EXAMPLE OF A TRANSITION MATRIX FOR THE CUNY MODEL

University's ethnic mix. To gain insights into the effects of such programs it was decided to include ethnic classification as a student descriptor.

Also of interest are enrollment breakdowns by "means of entrance" to CUNY. Students may be admitted from regular NYC high schools, out of New York City or New York State, the special programs (SEEK and College Discovery), or the "outside world," including transfers from the evening division and private colleges. Source of entrance, then, was chosen as a second student descriptor or characteristic.

All data outputs are based on the enrollment of full-time day session matriculants and special program students. With the model specifications formed to reflect these conditions and the ones discussed above, the necessary data could then be gathered.

In modeling student flows at CUNY, total students, first-time freshmen, and upper-level entrants were vectors rather than matrices of students. A vector of total students was cycled through a transition matrix, vectors of first-time freshmen and upper-level entrants were added to the result, and each element in this new vector of total students was multilpied by a vector of percentages which allocated the students among the categories of characteristics. In the newer forms of the model, it might be said that this apportionment is carried out for the first-time freshmen and upper-level entrants separately and before cycling through a transition matrix.

As might be expected, the historical data required for each year upon which the projections would be based were as follows:

(1) vector of first-time freshmen grouped by the major classification scheme;

(2) vector of upper-level entrants grouped by the major classification scheme;

(3) for each component of the major classification scheme, a vector of percentages describing the apportionment of students among the categories of characteristics being used as student descriptors.

In addition, for the first historical year, a vector of total students grouped by the major classification scheme and corresponding to the "starter" matrix of the present form of the model would be required. Analogously with the starter matrix, the starter vector would involve total "head-count" of students in the appropriate year.

In that which follows reference to the vectors of percentages describing the apportionment of the students among the categories of descriptive characteristics is made in terms of "Output Breakdown Vectors (OBV)" and the matrix formed by all OBV for a given year is called an output breakdown probability matrix (OBPM). As will be recalled, the need for such vectors or matrices in the newer versions of the model is limited to those characteristics which vary in some irregular manner over time.

Of the five facets to the data set necessary for implementation of the prototype, the starter vector, vectors of first-time freshmen, and vectors of specifically defined student totals are taken directly from aggregated historical records. The transition proportions, however, are not available in the records, and must be developed from other available information.

The proportions in each year's OBPM, q_{ij}, (See Figure 13) can be obtained by dividing the number of classification i students in category j by the total number of classification i students. For example, q_{32}, the likelihood that any Senior College freshman is Puerto Rican, is equal to the number of Puerto Ricans in the senior-college freshman class divided by the number of all Senior College freshmen. Only one year of historical data, 1967, was available to describe ethnic distribution. Subjective estimates of yearly percentage changes in ethnic distribution over the years dating back to CUNY's prior Master Plan (1964) were applied in reverse, starting from the 1967 figures, to find the "data" for 1965 and 1966. Values from which to obtain the source of entrance probability elements were taken directly from the aggregated enrollment and admissions forms.

	Ethnic			Source					
Level	Negro (1)	Puerto Rican (2)	Other (3)	Regular N.Y.C. H.S. (4)	Out of City (5)	Out of State (6)	Outside World (7)	SEEK (8)	College Discovery (9)
Comm. Coll. Frosh (1)	q_{11}	q_{12}	q_{13}	q_{14}	q_{15}	q_{16}	q_{17}	q_{18}	q_{19}
Comm. Coll. Soph (2)	q_{21}	q_{22}	q_{23}	q_{24}	q_{25}	q_{26}	q_{27}	q_{28}	q_{29}
Sen. Coll. Frosh (3)	q_{31}	q_{32}	q_{33}	q_{34}	q_{35}	q_{36}	q_{37}	q_{38}	q_{39}
Sen. Coll. Soph. (4)	q_{41}	q_{42}	q_{43}	q_{44}	q_{45}	q_{46}	q_{47}	q_{48}	q_{49}
Sen. Coll. Jun. (5)	q_{51}	q_{52}	q_{53}	q_{54}	q_{55}	q_{56}	q_{57}	q_{58}	q_{59}
Sen. Coll. Sen. (6)	q_{61}	q_{62}	q_{63}	q_{64}	q_{65}	q_{66}	q_{67}	q_{68}	q_{69}

FIGURE 13

GENERALIZED OUTPUT BREAKDOWN PROBABILITY MATRIX (OBPM)

While, again, much of the required data could be taken directly from aggregated historical records, the transition proportions were not available in the records and had to be estimated on other bases. The component probabilities of a transition matrix are proportional to the yearly movements of students from positions within the system to other positions within or outside it. By the nature of an educational system some of these probabilities are very close to zero, for a senior college junior will ordinarily not become a sophomore or a freshman, a freshman generally will not become a junior or senior by his next year, and so on. Therefore, before trying to evaluate any of the probabilities, it is necessary to look at their meanings in the context of the real CUNY system.

Figures 14 and 15 diagram student flow through the real CUNY system in notation as defined in those figures. The diagrams show all inputs to and outputs from each classification in the system. In Figure 14 Regular (Reg) and College Discovery (CD) inputs to the freshman class (F) make up the level #1 element of the T vector (vector of first-time freshmen). The input of year (k-1) freshman to the freshman class of year (k) represents the portion of year (k-1) freshmen who stay back to remain freshmen in year (k); as a percentage of all (k-1) freshmen, this flow is equivalent to a_{11} in the transition matrix (AMX). Similarly, the input of year (k-1) sophomores to the sophomore class of year (k) determines a_{22}, and the flow of stayback freshmen for the year k, gives a_{11} of the kth year transition matrix. There is flow between the system and the Outside World (OW) from all classifications. Record forms state the flow from the outside world to CUNY only in terms of one component to Community Colleges (CC) and one to Senior Colleges (SC). Assumptions were made that permitted these two components to be split into flows to each of the six respective levels; the Community College component is split evenly between freshmen and sophomores, while the Senior College component is divided into 20% freshmen, 60% sophomores, 20% juniors, and no seniors. (Notice that there are no input arrows to Senior Level from the Outside World in Figure 15.). Flows from CUNY to outside world occur at all levels. These attrition totals are given in aggregated attrition reports by year and classification. Dividing the year k absolute flow values by the total enrollment in the corresponding classification yields the a_{ik}, $i = 1,\dots,6$ of the year k transition matrix. In Figure 14, there are seen to be two-way yearly flows of students between Senior College and both levels of Community College. Figure 15 shows these flows from Senior College perspective. The set of specific level-to-level intercollege transfers existing in CUNY was outlined by planning officials at CUNY. All Senior College flows to Community College freshmen level originate from the freshmen class of Senior College; thus, a_{31} represents this flow and $a_{41}=a_{61}=0$. All Senior College flows to Community College sophomore class and are therefore represented by a_{42}, while $a_{32}=a_{52}=a_{62}=0$.

Notation Key, Figures 14 and 15

Reg - regular first-time freshmen
CD - new College Discovery program freshmen
F - freshman class
S - sophomore class
OW - outside world
SC - senior colleges
G - graduates to outside the system
SEEK - new SEEK program freshmen
J - junior class
SR - senior class

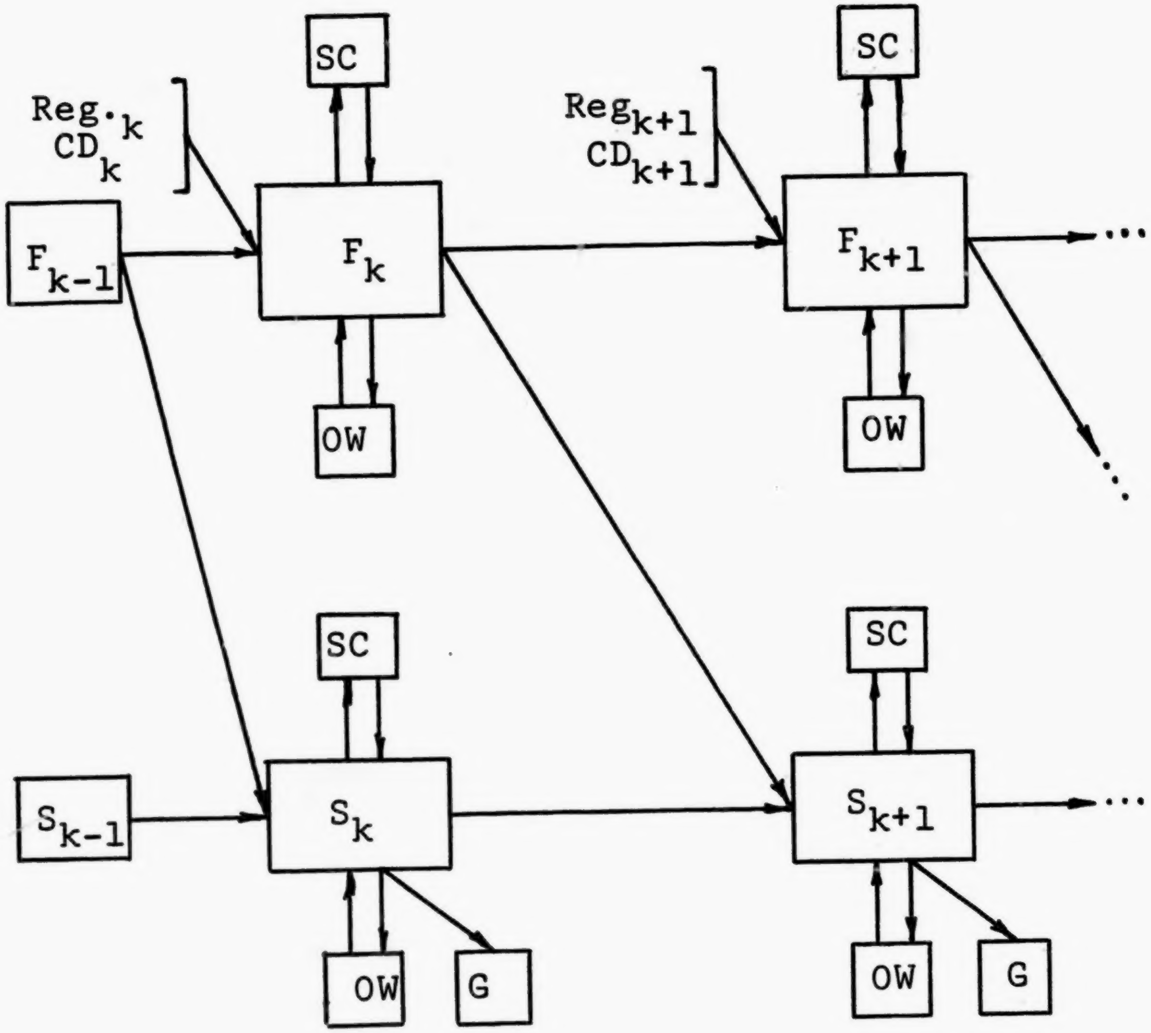
Reg.$_k$
CD$_k$
Reg$_{k+1}$
CD$_{k+1}$
SC
SC
SC
SC
F_{k-1}
F_k
F_{k+1}
S_{k-1}
S_k
S_{k+1}
OW
OW
OW
OW
G
G
...
...
...

FIGURE 14

STUDENT FLOW - COMMUNITY COLLEGES

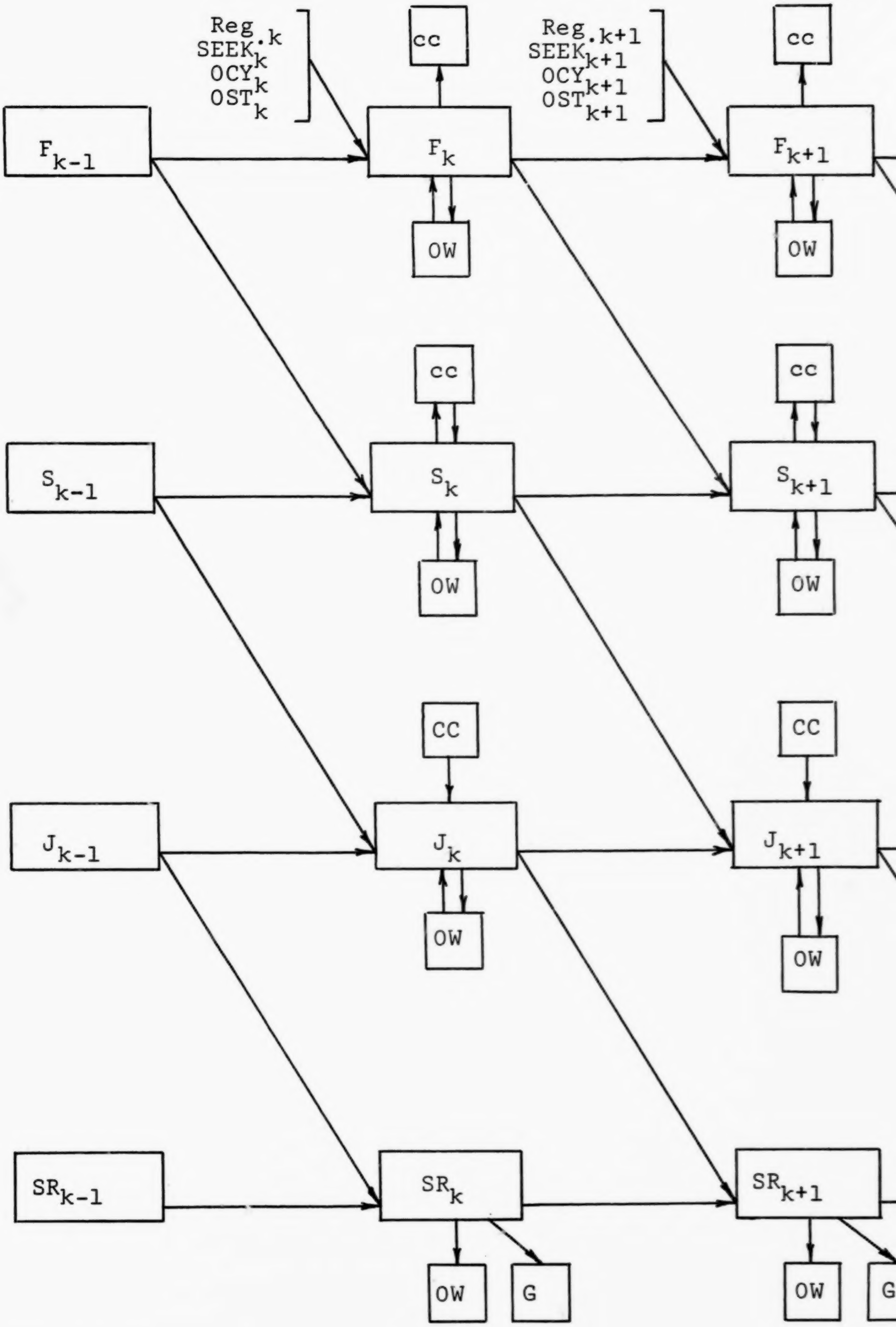
Reg.k
SEEKk
OCYk
OSTk
cc
Reg.k+1
SEEKk+1
OCYk+1
OSTk+1
cc
Fk-1
Fk
Fk+1
OW
OW
cc
cc
Sk-1
Sk
Sk+1
OW
OW
CC
CC
Jk-1
Jk
Jk+1
OW
OW
SRk-1
SRk
SRk+1
OW
G
OW
G

FIGURE 15

STUDENT FLOW - SENIOR COLLEGES

Transfers are allowed for qualified Community College freshmen to Senior College. All of these flows go to the sophomore level and correspond to a_{14}, so that $a_{13}=0$. From the sophomore level, Community College students may graduate and go on to junior level studies in Senior College (a_{25}); they may also transfer without graduating, in which case they go to the sophomore level (a_{24}). Besides transferring, staying back, and dropping or being cast off to outside world, the only other output from the Community College sophomore class is through graduation to outside the system (a_{27}). Therefore $a_{21}=a_{23}=a_{26}=0$. Figure 15 shows the components of the third element of T to the Regular, SEEK, Out of City and Out of State. Finally, it is seen that the lines of "normal" progress through the system are represented by F_k to S_{k+1}, S_k to J_{k+1}, and J_k to Sr_{k+1}, the probabilities associated with these flows being a_{12} for Community Colleges and a_{34}, a_{45}, and a_{56} for Senior Colleges. Of course, a student may either remain at his level or progress to a higher level after a year, but he generally will not make negative progress. Therefore,

$$a_{21}=a_{41}=a_{51}=a_{61}=a_{52}=a_{62}=a_{23}=a_{43}=a_{53}=a_{63}=a_{54}=a_{64}=a_{65}=0.$$

Finding values for all a_{ij} in a transition matrix amounts to quantifying the flows represented by all output arrows from year k levels. It is seen that many of these are not feasible transitions and hence many flows are zero. Some others are directly defined or easily calculable (given subjective estimates) from enrollment, admissions, and attrition reports. The only flows that are not available here are those of "staybacks" (i.e.: a_{11}, a_{22}, etc.) and those of normal progressions (i.e.: a_{12}, a_{34}, a_{45}, a_{56}) through a college. They are represented by the horizontal and diagonal (pointing towards lower right) arrows of Figure 14 and 15. All other inputs and outputs are essentially known. Notice that if just one of the unknowns is found, the others (in that particular year) are automatically determined. That is, if the senior college F_k to F_{k+1} flow is found, it can be added to the F_k transfer and outside world flows (which are known) to obtain a quantity which when subtracted from F_k yields as a difference the only remaining output flow, F_k to S_{k+1}. In terms of transition probabilities,

$$\sum_{j=1}^{8} a_{3j} = 1,$$

that is, the row sums must equal 1, but as shown above,

$$a_{32}=a_{35}=a_{36}=a_{38}=0,$$

therefore, $a_{31}+a_{33}+a_{34}+a_{37}=1$;

and letting the known sum, $a_{31} + a_{37} = C$,

$$a_{34} = 1-C-a_{33},$$

so that knowing a_{33}, the freshman stayback rate, is equivalent to knowing a_{34}, the freshman to sophomore flow rate. Since all inputs to S_{k+1} are known previously except for the F_k to S_{k+1} and S_k to S_{k+1} flows, this newly computed parameter, a_{34}, by determining F_k to S_{k+1} also determines the sophomire stayback rate, a_{44}, from year k. The rest of the unknowns are calculated by this simple difference technique in the light of the facts that

$\sum_{j=1}^{8} a_{ij} = 1$ and the sum of the inputs to a level must equal that level's total enrollment. Since the unknowns are interdependent, the problem is reduced to that of finding just one of the unknown flow rates. The solution is seen in looking at the inputs to F; they include T (which is given), E (which is given), and staybacks from the previous year. Symbolically, then, for any year k, if V_{3k} represents the total number of classification 3,

$$a_{33} = \frac{V_3 - T_3 - E_3}{V_{3(k-1)}},$$

where $V_{3(k-1)}$ is senior college freshman enrollment of the previous year.

In the model, first-time freshman vectors (T) are projected from the corresponding vectors in the historical data. Freshman admissions at CUNY, however, are a function solely of space available. Knowing the distribution of New York City high school seniors' academic averages, planners simply draw the cutoff line at a percentage selected to give the desired number of acceptances and hence expected admissions. In fact, the CUNY administration can plan on yearly admissions goals and then see that they are met by drawing the appropriate cutoff line each year. The 1968 Master Plan states explicitly what first-time freshmen admissions to senior and community colleges should be for the years through 1975. It is therefore not the CUNY model's task to project them, but to accept these T_i, i = 1968,..., 1975, as known input to the model. The model was appropriately (and easily) modified to do so.

A change of form was made shortly thereafter. The transition matrix contains a_{ijk}'s to reflect average behavior, by the very nature of these probability elements; but it is known that performance of Special Programs students (those admitted through SEEK and College Discovery) differs from that of the "regular" matriculants. Although the SEEK and College Discovery students have historically made up a very small portion of total enrollment, growth of these programs as well as inception of new ones adopted in August, 1968 will boost the total enrollment through special programs (SP) to increasingly significant levels up through 1975. It was therefore decided to flow the special programs population through a transition matrix of its own developed from historical records of SEEK and College Discovery students.

Upon adoption of the new programs CUNY planners were at once faced with the problem of judging their effects on total enrollment and ethnic distribution of all students. To isolate these effects the CUNY model was programmed to handle different data sets, one concerning all regular full-time day matriculants and the other concerning students in SEEK, College Discovery, and the new special programs. This represents an application of the model's ability to respond to contingency questions, for in adding the new educational programs to the model, planners were essentially asking "*What* would be the short and long run effects on the system *if* (a) new program(s) were added?" In terms of data requirements they needed only supply yearly T vectors for the new program(s) since T for SEEK and College Discovery were already known, all special program students enter as Freshmen (E=0), historical V's for SEEK and College Discovery were known and for new programs were equal to zero, the transition matrix had been already calculated, and the OBPM's were available through Dean Hollander's office. The T vectors were given by the CUNY administration on the basis of the construction of the new programs. To the original program, the split meant having only to subtract SEEK and College Discovery of all T vectors and to recalculate a shortened OBV without the SEEK and College Discovery elements. The Special Program data set was expanded to include the data of the new special programs within each set representing a different combination of special programs whose effects were to be examined. Since this amounted to subjecting the simulated system to six different possible sets of forces, the Special Program section is termed the "Contingency Model"; the other section, having only one data set, is the "Constant Model," though this name is not meant to imply that contingencies cannot be tested on it. Planners can ask questions of either model by changing the appropriate data inputs: a subsequent run would show the system's response.

Since the nature of the planning process demands that many contingencies be tested under several assumptions, the model was adapted to a real-time computing system — the model was put "on-line". Program changes and the addition of English language statements to ease communication made for the following specific user features in the on-line model:

(i) Selection of Output Displayed. The user need not receive the entire model output if he is interested in only specific parts of it. He may order that any combination of any number of the parts (AMX,T,E,V, OBV) be printed (for specific projected years in the cases of AMX and OBV).

(ii) Dictation of Number of Projected Years. Although because of core limits the model is set up to project only eight years (1968 through 1975), the user may not be immediately interested in all of them. He can input at a run's outset the number of projected years to be included in printout.

(iii) Ability to Change Projected Values. A planner might have reason to believe that the trend implied by projected values does not agree with his educated intuition. If so, he can change any projected value(s) that differ from his expectation. Any change thus made also affects other projected values. The user may choose either of two ways in which this influence is manifested: through the "dynamic" or the "episodic" update, as discussed in Section II of the report.

3. CUNY: Evaluation and Conclusions

The CUNY simulation model was set up not only as a direct aid to City University planners but also as a prototype from which to develop a systematic approach adapting the general model to a specific educational system, and measuring the effectiveness of its methodology in that system. After specifications to orient the model's output to particular planning needs were set, a general technology was introduced for development of initialization data from yearly aggregate reports. Evaluation of the devised application techniques was made with respect to the original objectives of the simulator. The two general areas of focus were:

1. accuracy of the projections; and
2. usefulness of the simulation's ability to react to contingencies.

Since the CUNY model projections are made on the basis of three data points, any irregularity in a data point from a given year has significant effect on the projected value of a variable. Projection from a greater number of observations reduces the potential impact of such irregularity. It is to be expected, then, that additional years of data collection at CUNY will bring more reliable projections.

A second area of evaluation reflects the accuracy with which the model represents the CUNY educational system. The greatest value of any simulation model is in its capacity to help the planner contemplate "what-if" questions. It is in this capacity that the CUNY model has proved most useful; the latter helped to identify both short and long range effects of the additional special programs considered by the university administration. When the model was put on a real-time basis, the system was tested "on-line" for sensitivity to several hypothetical policy decisions. One such "decision" dictated the admission of five hundred additional special programs freshmen in 1970. The immediate output response showed the expected distribution of these students in years 1970-1975. Thus, CUNY planners could judge incremental effects of this one event on particular system components in the long run. The speed of the time-sharing output was found to be as important as the resultant figures themselves. It is often the case that City University planners wish to find the causal action required to produce a desired effect on enrollments. The real-time-system enables them to "try" various actions in succession to deduce a most suitable policy.

Model uses presently being considered include applications to university budgeting and yearly revisions of the Master Plan. The development of a university-wide information system will greatly increase the potential for such a simulation while at the same time it will enlarge the awareness of the utility of the model as part of an expanding planning medium.

C. Rensselaer: Unit Record Sampling

The implementation of the prototype model at CUNY provided experience in initializing the planning model in the context of a large educational system. As we have seen this system had many diverse data sources, but the structure of the student information both within and between these individual sources did not lend itself to easy and rapid initialization of the simulation. On the contrary, preparing the simulation for use at CUNY required an amalgam of methods for gathering the requisite data. The ability to draw data from an homogeneous data system could potentially have alleviated many of the problems associated with the CUNY study.

Rensselaer Polytechnic Institute was chosen as a representative institution within which the planning model could be utilized by providing input data from a sample of unit records. In addition, a parallel attempt was undertaken to utilize subjective estimates of the academic deans at Rensselaer as an independent measure of student flows in order to provide a measure of validity to both the input and output (of the simulation) generated by sampling unit records. This attempt at validating the simulation by using an independent set of data inputs proved impractical. None of the academic deans felt qualified in providing accurate flows either within their school or between the five separate schools of Rensselaer. Although the registrar might be able to provide such estimates, the level of disaggregation required by the model at Rensselaer precluded the possibility that the registrar's office could provide data on the precision desired while maintaining an independence from the students' unit records. Consequently, the study at Rensselaer concentrated on a sampling of unit records augmented by several aggregate reports previously prepared by the registrar's office.

The initial phase of the unit record sampling study helped determine the form and content of the unit record data and involved a detailed investigation of the educational structure in order to obtain historic knowledge of student characteristics and "aging" processes.

The preliminary study of the availability of data set the ground work for the development of the sampling form. This sampling form was structured so as not to confine the sampler to any one sampling design.

The sampling form involves a row tabulation of information from individual student personal record cards (PRC forms). From the information extracted separately from each sampled student's PRC, a historic trace of his aging process is recorded on the sampling form in terms of the classifications and characteristics delineated by the model (see Figure 16).

The "class profile" is the record in which each student's historic movement through the educational system is recorded. Corresponding to each level, the appropriate curriculum can be recorded for each student. Space is alloted for two years at each level (where the second year is for a repetition of the level). The other information is required for categorization of each student, for the location of his entrance and exist from the system, and for credit hour distributions. The class profile of all students can be added up to give empirical transition frequencies. By dividing through by the row sum for any matrix of frequencies, the transition probabilities are calculated.

1. File Organization

A brief description of the file organization at Rensselaer is presented to provide an understanding of the difficulties of randomly sampling student PRC

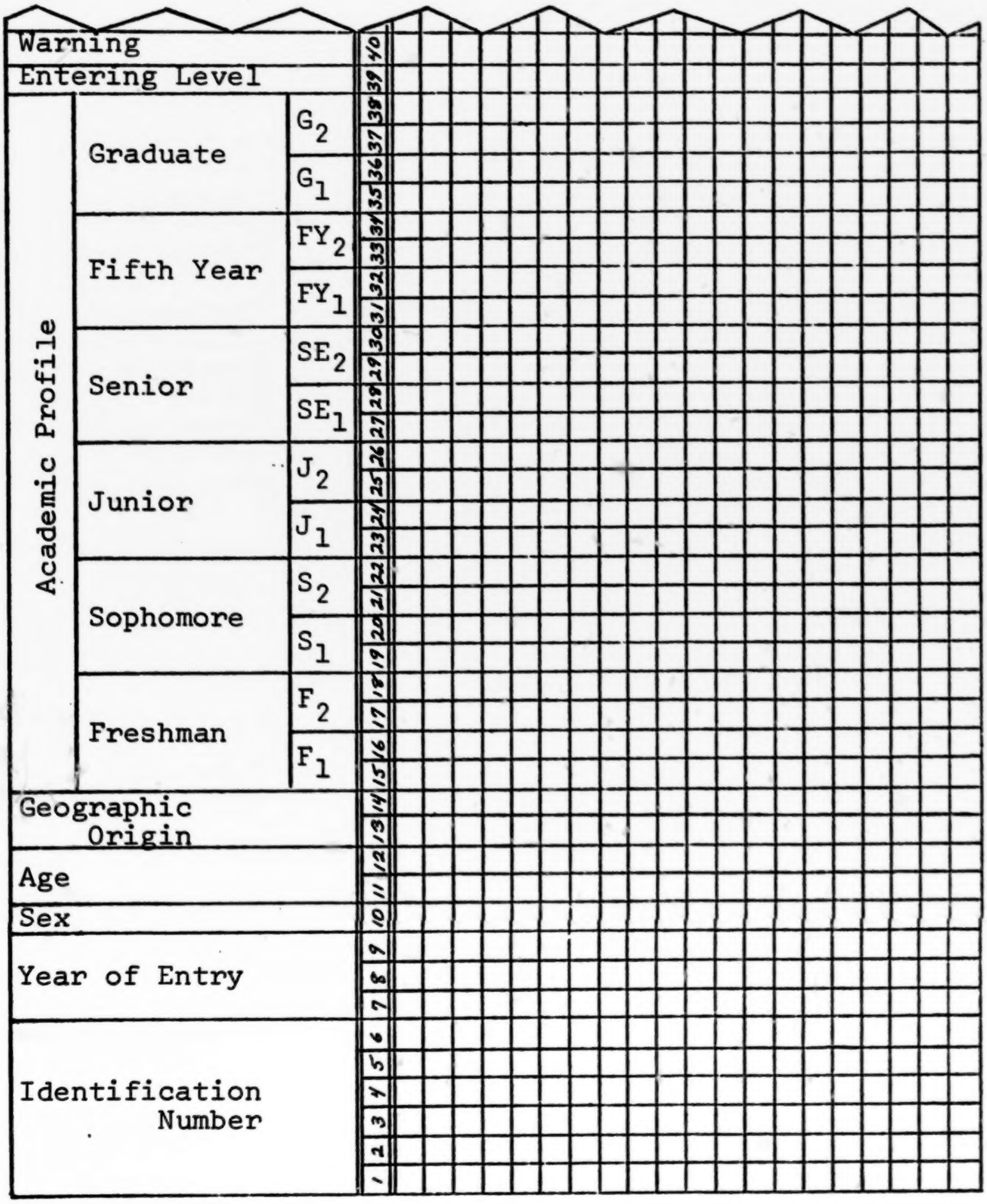
Warning
Entering Level
Academic Profile
Graduate
G_2
G_1
Fifth Year
FY_2
FY_1
Senior
SE_2
SE_1
Junior
J_2
J_1
Sophomore
S_2
S_1
Freshman
F_2
F_1
Geographic Origin
Age
Sex
Year of Entry
Identification Number
40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

FIGURE 16

R.P.I. UNIT DATA COLLECTION FORM

			80
Annual Credit Hour Load	Graduate	G_5	79 78
		G_4	77 76
		G_3	75 74
		G_2	73 72
		G_1	71 70
	Fifth Year	FY_2	69 68
		FY_1	67 66
	Senior	SE_2	65 64
		SE_1	63 62
	Junior	J_2	61 60
		J_1	59 58
	Sophomore	S_2	57 56
		S_1	55 54
	Freshman	F_2	53 52
		F_1	51 50
Degrees Obtained	Doct.	Year	49 48
		School	47
	Mast.	Year	46 45
		School	44
	Bach.	Year	43 42
		School	41

FIGURE 16 (CONTINUED)

forms. The arrangement of the PRC forms contributes not only to the difficulty or ease of sampling, but also helps to determine the sampling design.

Inactive students or those who have already graduated or dropped from school are filed as a group in alphabetical order. All active full-time graduate students are also filed together by the order of the alphabet. Part-time graduate students are grouped in the same fashion. Finally, the graduated students of the past year (in this case 1968) have been placed in a separate file by order of the alphabet. A compounding problem arises here because undergraduate and graduate records of students who have matriculated in both the undergraduate and graduate degree programs are placed on two different PRC forms. A student who has completed an undergraduate degree program and is now an active graduate student or has received a second or third degree in the past year would have one inactive PRC form and one either active PRC form or graduate PRC form, depending on his situation. Fortunately, the PRC forms are cross referenced so that each student's entire record can be sampled. It should be stressed here than when a student is chosen for the sample (the choice being dependent on the design of the sample), the entire profile of a student while in attendance at Rensselaer is sampled. The reasoning is that the summations of characteristics and transitions of individuals who "age" over their matriculation at Rensselaer is the procedure by which the computer model transforms individualized data into transition probabilities and matrices of entering students. An alternate procedure consists of sampling students for only a particular transition, for example junior-senior transitions. Such a procedure may be equally as valid and could be conducted with less expenditure of effort depending on the file organization at the institution being studied.

The set of data required by the sampling form can be generated from the individual students' PRC form. Other information had to be collected for the initialization of the model, but was dependent upon the sampling design.

2. A Sampling Design for the Acquisition of Unit Record Data

Once the Rensselaer information system of unit record data had been analyzed, the ensuing task was to compare the effectiveness of all the possible sampling designs to determine the best alternative scheme. Through the process of relating the unit record information to the model's data requirements, two criteria by which to select students for the sample were chosen: the criteria of selecting students by entering year and graduating year were used to formulate two alternative sampling designs.

The procedure of randomly choosing students from lists of the entering population will hereafter be defined as the forward selection design. The advantage of this procedure is that every student enters the system only once (although they may re-enter several times). Students who permanently withdraw (voluntarily or involuntarily) before they graduate are as likely to be chosen from the population as those who eventually graduate. Upper-level entrants as well as first-time freshmen are listed together (in alphabetical order) so that transfer students to Rensselaer also have as great a chance being sampled as other students. Consequently, all possible categories of students in the population are listed by entering year. However, the alphabetical listing of entering students by name only precludes any stratification by curriculum. Therefore the forward selection process is an unbiased, simple random design.

The backward selection procedure consists of randomly choosing students from graduation lists each year. The major advantage to this design is that a stratification by cirriculum could be established. Stratified sampling by curriculum permits the sampling plan to take advantage of differing transitional distributions between schools at Rensselaer and thus a more nearly optimal level of efficiency can be achieved for a given sample size at Rensselaer as a whole. However, this stratification is conditional upon the assumption that the transition probabilities of students who make transitions and graduate do not differ from those who make transitions up until some level and then permanently withdraw. If this assumption is not entirely reasonable, then the stratification is only an approximation to a division by curriculum. The advantage of a stratification by curriculum is that we are given enough information on each curriculum to calculate an estimate (and the variance) of the proportion or number of students in a curriculum at a given level for a certain year (e.g., the number of juniors in engineering in 1968). The disadvantage of the backward selection procedure is that students who withdraw and do not return also do not graduate. Hence they are not on the graduation lists and are not in the population from which the sample is drawn. However, the attrition numbers by curriculum, level and year were available through 1962 and could be adequately estimated for the remaining years.

Admissions personnel are concerned with the association of categories with students who withdraw (voluntarily and involuntarily). Academic planners however, may be more interested in a "finer" breakdown of enrollment projections and be willing to sacrifice some accuracy concerning withdrawals in order to obtain additional disaggregation. Bias in these estimates concerning withdrawals may be negligible if the assumptions above are reasonably correct. If such is the case, then the backward selection procedure has greater efficiency than the forward selection procedure.

The actual method chosen for a given educational system is a function of the emphasis which the educators wish to place on their use of the simulation. Thus, at least in the case of the testing of the prototype at Rensselaer, a tradeoff existed between two possible sampling plans: one plan better suited for estimating flows between curricula, and another plan designed to obtain a less accurate but broader picture of all flows encompassed by the institution. In the experiment conducted at Rensselaer the emphasis was placed on estimating between curricula flows; since the purpose of the study was to investigate a sampling plan that would produce the required disaggregated information.

The magnitude of the sample size from each curriculum was assessed with respect to its expected number of transfers. Those transfer-oriented curricula with the largest number of off-diagonal transitions would, naturally, require larger sample sizes for a given level of precision. Consequently, a full enumeration was made on those curricula most susceptible to transfers. These included the School of Management and the School of Humanities and Social Sciences. The three other schools (Architecture, Engineering and

Science) were arbitrarily allocated a fifty percent sample.

Estimation by a curriculum stratified random sample was pursued through the backward selection process. The quantity being estimated was the sum of the number of people from each of the components of the major classification scheme (see Figure 17 on the following page) who made a transition to a classification at the same or an adjoining level, withdrew or graduated. Students were sampled by graduating year from the classes of 1962-1968. The six levels for which transition probability matrices were developed include freshman, sophomore, junior, senior, fifth year (professional), and graduate, as is indicated in Figure 17.

In estimating the number of students who transfer into any classification from any other classification, two types of student can be drawn from each stratum. In the category of interest are those who age to the jth classification; the other category includes those who do not age to the jth classification. Therefore, there are only two categories of interest in estimating the frequency of a transition to a given classification when sampling from each stratum. Since the design consists of selecting individuals from a finite population of students, the samples will not be independent. The probability of choosing an individual who has made a given transition does not remain constant

- Freshman
  - Architecture
  - Engineering
  - Humanities
  - Management
  - Science
- Sophomore
  - Architecture
  - Engineering
  - Humanities
  - Management
  - Science
- Junior
  - Architecture
  - Engineering
  - Humanities
  - Management
  - Science
- Senior
  - Architecture
  - Engineering
  - Humanities
  - Management
  - Science
- Fifth Year
  - Architecture
  - Engineering
  - Humanities
  - Management
  - Science
- Graduate
  - Architecture
  - Engineering
  - Humanities
  - Management
  - Science

FIGURE 17

THE MAJOR CLASSIFICATION SCHEME AT RENSSELAER when large samples are taken without replacement from finite populations. Thus the hypergeometric distribution provided the underlying model for developing the appropriate sample sizes from all curricula (schools) and levels.

Additional data were required to initialize the model and were extracted from aggregate reports available in the registrar's office. First, total population frequencies by curriculum, level and year were collected from fall enrollment distribution sheets from the fall of 1958 through 1964. Only the first four years of first-time freshmen by curriculum were actual count data. The last three were weighted average estimates by curriculum taken from projections of past values of total first-time freshmen.

Upper-level entrance frequencies by curriculum and year of entrance were amassed from information kept on each student transferring into Rensselaer. These students were listed in the alphabetical order of the college they transferred from, the date of transfer, and the level of entrance. The entrance frequencies were not available for graduate student entrants.

Attrition frequencies of undergraduate students by curriculum and year were available in the attrition study cited above. Again, the first four years of data were available at the required level of disaggregation. For the last three years, only the total attrition figures by level were available. It was thus assumed that attrition by curriculum was simply proportional to the numbers of students in each curriculum. This provided attrition estimates by curriculum, level and year. Information on graduate student attrition frequencies was not available, as was the case for their entrance frequencies.

In order to complete the model initialization at the graduate level certain assumptions were made after discussion with the registrar's office. These were:

1. Thirty percent of the population of students by curriculum withdrew each year.
2. Fifty percent of the population of students by curriculum graduated.
3. Sixty percent of the population of students by curriculum are graduate level entrants.

Thus stratified sampling of unit records, augmented by the results of studies carried out by the registrar's office, provided the entire input set for the prototype model at RPI. Computer time limitations and budgetary constraints have to this time prevented an adequate testing and evaluation of this prototype.

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It should also be recalled that the model was designed to operate in a batch processing mode as opposed to the time-sharing modes of the models employed at CUNY and HVCC. While the basic structure of the model is identical regardless of the operational mode employed, the process of converting the unit record information into an aggregated format has proved to be both time consuming and costly.

3. Unit Record Sampling: An Evaluation

Sampling of unit records at individual institutions should provide the most precise as well as the most accurate measurement of student flows based upon historical data. However, the added precision and accuracy of the estimates which accrue must be evaluated with respect to the costs required to obtain such estimates. In addition, the following factors must be considered:

(a) Designing the sampling plan for obtaining unit record data requires a detailed knowledge of the educational system under consideration. For example, the designating of strata within RPI could only be undertaken with full comprehension of the various schools, curricula and possible transitions within RPI. If unit record data were to be obtained from diverse institutions then one must expect that differing sampling plans would have to be designed contingent upon the nature of the particular institution in question.

(b) It is difficult to estimate an optimal sample size because of the lack of information about the parameters to be estimated in a given educational system, e.g., the proportion of transfers among the college in a statewide system. In order to attain optimality, multistage sampling must be undertaken in order to enable initial estimates of sample size; but such a procedure will not be practical for a range of widely differing institutions. While parametric evaluation _per se_ may not be critical from a planning standpoint, the operational problems involved with establishing criteria for sample size can prove formidable.

(c) Along with determining sample size the problems of file content and organization must be considered. These will not be invariate through a range of institutions. Definitions of classifications depend upon the needs of the planners at a particular institution or within a particular system as seen by the analysis of the information at CUNY, where unit record data could not be used for precisely this reason.

(d) The intermediate steps necessary for conversion of unit record data to a form readily processible by machine can be costly. At Rensselaer the costs for sampling and processing this information exceeded $1.05 per student. While such conversions will become more routine as experience with this process increases, the diversity between institutions may prevent this problem from receding to a more manageable level.

The large expenditure required when utilizing units record sampling or the input medium compels the simulation user to have a clear idea of the uses to which he intends to put the planning simulation. In recognition of these costs the planner might envision a stagewise approach to model implementation within a given system. Thus, as a first approach, data could be obtained from aggregate sources and from "knowledgeable persons". The experiences gained from utilizing a model initialized in this manner will enable a planner to specify the parameters of greatest interest and such a specification can then aid in the further development of a sampling plan to obtain unit record data.

As the individual institutions within the State move toward greater sophistication in their data management techniques the necessity for sampling individual records may, in fact, be eliminated. It may be possible to directly extract information from the student files maintained by the institutions. For instance, Rensselaer is presently completing construction of a magnetic tape oriented student information system, and Syracuse University has an extensive information system already in use. Once the simulation model had been initialized (perhaps by sampling unit records) it would be possible to maintain and update the model by collecting data presently being stored on such institution files. The exact nature of the data which could be extracted from these computer oriented files will be a function of the final designs of the model as well as the state of the student information system at the individual schools.

D. Hudson Valley Community College: Subjective Estimation

1. The Research Instrument

An introduction to the student information system of Hudson Valley Community College was obtained through meetings with the president of the school and his administrative assistants. Once the major classification scheme for representation of HVCC had been decided upon, the designing of a questionnaire for obtaining the required data could commence.

The academic programs of HVCC are classified into six divisions. Within each division there are two levels, junior and senior, corresponding, respectively, to the freshman and sophomore levels at a four-year college. The major classification scheme was thus composed of twelve components: six divisions times two levels in each, as shown in Figure 18. At the suggestion of the representatives of HVCC and taking

Business - Junior
Senior

Engineering Technology - Junior
Senior

Health Technology - Junior
Senior

Liberal Arts - Junior
Senior

Physical Education - Junior
Senior

Physical Science - Junior
Senior

FIGURE 18

THE MAJOR CLASSIFICATION SCHEME FOR HVCC into account the capacity limitations of the time-shared computer system, information was collected only on the characteristic "sex."

The research instrument used for collection of subjective information at HVCC is given in Appendix B. The two most important considerations in the design of the questionnaire were its simplicity of use, and its completeness in terms of the data requirements of the model as enumerated in Section II. The most difficult portion of the design was at the interface of these two considerations, particularly with regard to the obtaining of transition matrix elements.

As can be seen on the last page of the sample questionnaire, some of the data requirements of the model were straightforwardly fulfilled: combining the lower block with headcount data by division, year and level yielded the matrices of upper-level entrants required for each of the (five) years' historical data being collected. The top block (same page) was to be used for checking the operations of the model during the simulated historical years, and the first line in this block yielded the so-called "starter matrix" for the first year for which complete data were available, 1963.

The matrices of first-time juniors were obtained by combining the "repeat" rate obtained from the estimates of the transition proportions with the headcounts, by year, of total juniors. By subtracting out of the total number of juniors the estimated number who were juniors in the previous year, an estimate of this year's first-time juniors could be gained.

Transition matrices were obtained "division-by-division", with an entire questionnaire yielding the same two rows of each year's matrix. Thus each of the participating administrators was required to estimate only "where his students were going," rather than "from whence they were coming" or both.

The only non-subjective data amassed for the HVCC model were those of the total college population "head count" for the Septembers of 1963-1967, inclusive. Had first-time junior counts been collected, the model ordinarily would not require the 1964-1967 totals; but, again, the latter were collected for calidation purposes.

At a divisional director's meeting, the participants were asked to complete the questionnaire. The latter was explained to them and estimates were obtained in approximately one half-hour. The trade-off inherent in this procedure was that between the rapidity of obtaining the estimates, and the cost of being forced to carry out the type of data development procedures used in the CUNY study. The general consensus of the directors was that their estimates would not be correct, and thus would not contain intrinsic utility for educational planning.

The historical data in the charts on the following page have been listed for the purpose of visual comparison with the output of the computer model for those years. In addition, the projected enrollments for 1968 and 1969, developed from the projection of historical values, are given. As stated in previous sections, it cannot be expected that the results will be highly accurate since no work has yet been done on identification of the independent variables upon which the regression equations are based.

2. Evaluation of the Collection Procedure

President Fitzgibbons of Hudson Valley expressed a desire to immediately utilize the HVCC prototype model as an aid to his intermediate range planning. As the President suggested, knowledge of the effect of two new community colleges (in Greene and Schenectady Counties) on the enrollments at Hudson Valley in the fall of 1969 and subsequently would be of great benefit to him in allocating educational resources for the faculty and staff requirements which will exist at that time.

The model has the capability of assisting in such a study if the required data are available; in this case, geographic origin data on expected student populations would have to be obtained. Such data could be developed by the model if historical geographic

	BUSINESS		ENG. TECH		HEALTH		LIB. ARTS		PHYS. ED.		PHYS. SCI.	
Year	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.
1963	268	117	426	247	145	40	175	75	0	0	40	6
1964	306	162	485	324	198	72	252	167	0	0	89	29
1965	309	278	558	337	230	108	224	203	0	0	97	64
1966	445	286	455	353	273	136	338	214	45	0	102	84
1967	607	313	485	262	279	152	386	332	82	35	103	76
1968	570	396	489	295	291	147	367	377	100	61	126	87

FIGURE 19

HVCC HISTORICAL DATA

	BUSINESS		ENG. TECH		HEALTH		LIB. ARTS		PHYS. ED.		PHYS. SCI.	
Year	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.	Jr.	Sr.
1963	268	117	426	247	145	40	115	75	0	0	40	6
1964	307	162	468	325	198	9	252	163	0	0	89	33
1965	415	273	543	327	230	106	224	203	0	0	97	66
1966	446	288	458	339	273	137	338	217	45	3	102	83
1967	607	313	497	263	279	152	386	331	82	40	103	78
1968	671	393	488	304	311	149	419	380	92	60	112	87
1969	755	447	484	262	336	196	466	428	113	71	118	94

FIGURE 20

HVCC HISTORICAL AND FORECASTED DATA AS REPRESENTED IN THE MODEL origin information were input. As stated, more core capacity (or reprogramming) of the pilot would be necessitated before additional categories of characteristics could be included in the HVCC model in the present time-sharing system. When an attempt was made to obtain the requisite historical data, if was found that the requirements of the model could not be fulfilled in the brief time available, since the geographic data were needed in terms of each of the components of the major classification scheme and did not exist in this form.

As has been stated, the participants in the experiment felt that their subjective estimates would not be correct. To test this hypothesis, the estimates obtained would have to be utilized by the model in the calculation of enrollments for the years 1963-1967. Comparison of these with the actual enrollments would point up any inconsistencies between the estimates and the real enrollment data. Instead, the estimates were systematically rearranged before input into the model, forcing them into internal consistency. Thus, for example, the given estimate of .50 for a particular transition probability might have been changed to .45 or .55 so that the cycling of a matrix of total students through the transition matrix would yield a result more in line with the (known) matrix of total students for the subsequent year. In actuality, it was found that the number of such changes was quite small — as were their magnitudes. Only about ten changes were made in the subjective estimates as collected; and these changes involved numbers of students ranging between 1 and 80. In the instances in which changes of the latter size were required, the researchers did not wish to "force" the data to too great an extent — and there are thus a number of disparities between the actual data collected and the historical data as represented in the model: again, these disparities were made explicit in Figures 21 and 22.

In view of the amount of time spent in preparing the questionnaire, and amassing and organizing the subjective information for HVCC, it would seen that the results, although not completely consistent, were highly promising. A mere half-hour was available for the entire data-collection proceedings including explanation to the participants of the instructions for filling out the questionnaire. If future sets of instructions are made more easily understandable, it is conceivable that questionnaires of the type constructed might be filled out more at the leisure of those from whom information was desired — and the internal consistency of the data obtained might thereby be improved. Even with one of the researchers in attendance, there was some difficulty with the instructions due to the fact that they contained language which, although familiar to the researchers, had been developed over time through work with the model and, in retrospect, could not have been expected to be clear to those for whom they were meant.

The participants had never been asked whether they felt they could give better estimates had the questions been somewhat different (although their results would have yielded the same information). This type of questioning might have been performed prior to the design of the questionnaire. For example, it might have been easier to estimate the in-system origins rather than the in-system destinations of students. Here, in effect, the person giving his subjective estimates would be asked "where are your students coming from" rather than "where do they go." In this case, the blocks into which estimates of transition frequencies would be put might be arranged in column rather than row form, with the single column heading representing the divisional director's own division, and the multiple row headings representing possible sources of student input into his division.

In view of the President's desire to use the HVCC model immediately, it seems fair to state that the latter has some utility for planning at Hudson Valley, but that this utility is, at present, limited to the extent that the data are limited — as was the case for the studies discussed previously.

SECTION IV

SUMMARY AND CONCLUSIONS

The purpose of this section of the report is to summarize the activities previously described and to discuss the results of the research activities undertaken. This applied research endeavor represents the second phase of an educational planning program conducted by the New York State Department of Education. Therefore, it is anticipated that the results of our activities will be evaluated, and decisions made concerning the implementation of the enrollment projection model described herein.

Phase I entitled "The Development of a Computer Model for Projecting Statewide College Enrollments: A Preliminary Study" recommended that a prototype simulation model be constructed prior to the full implementation of a Statewide projection model. The present study was undertaken to develop such a model and provide insights into its operating characteristics and relationship to an information system for higher education in New York State. A program was undertaken to both develop a prototype computer model useful for educational planning in the state and evaluate the required information on student characteristics available in representative colleges and universities. The model was programmed for an on-line computer system permitting ready access and man-machine interaction. It was evaluated at meetings of the Computer Model Advisory Committee and representatives of City University of New York, Hudson Valley Community College and Rensselaer Polytechnic Institute. The prototype model is currently operational and is available for use by institutions throughout the state.

The informational characteristics of the higher educational system in the State were sampled. A representative selection was made that included a two year college, four year colleges, both public and private, and a city university system. The availability of information on enrollment as well as an evaluation of usefulness of the simulation model developed were compiled for each of these case studies. The "case study" experience was extremely valuable in that it permitted interaction with educational planners at the local level. This interaction revealed deficiencies in the construction of the model and permitted evaluation of its characteristics. In addition, these planners were made aware of the services that would be available to individual institutions by a fully operational statewide planning model.

A. Conclusions: The Model

The model derived and discussed in this work is sophisticated, but remains a prototype; there are several modifications which should be considered before it is used in a full scale implementation. One of the most important of these has already been discussed, that of the assumption of independence between the transition probabilities and the personal characteristics of students. Such characteristics as ethnic origin and/or socio-economic status of parents have great bearing on the educational program of a student as modeled by the transition probabilities. Therefore, it will be advantageous to develop separate transition matrices concomitant to these characteristics so that the effects of special programs instituted in view of them may be evaluated. The importance of this assumption is, of course, a function of both the characteristic under consideration and the prospective use of the model. It is recommended that research be initiated on the relationships between characteristics and transition probabilities.

Research should be undertaken to determine the nature of the independent variables which are used in the regression equations. Not only should the relevancy of these variates be explored, but also an attempt should be made to determine the "best" form for various sets of regression equations; that is, those sets which will provide the "best fit" to the historical data. For this to be accomplished considerable data concerning these variables will have to be collected.

The prototype model developed will be valuable in determining the sensitivity of the variables as well as testing the predictive abilities associated with them.

Since the model is a prototype, the actual programs being used are not in final form. Experience with the data collected during the case studies has indicated certain deficiencies in the program used. For example, in the statewide model, the input of a "what if?" type question involving the addition of numbers of first-time freshmen may result in additional graduate students for the following year. Obviously, freshmen should not become graduate students until they spend at least four years in the educational system. The problem arises in the definition of the components of the major classification scheme being used. The levels of the four year schools are only undergraduate and graduate: as will be recalled from the recursive relationship (equation 13) developed in Section II, the structure of the model is such that the additional first-time freshmen will be allocated among all of the components of the major classification scheme for the subsequent period. It is thus apparent that once the major classification scheme has been decided upon, such problems as the latter must be obviated through special purpose programming. Similar modifications should of course be made as experience with the simulation grows.

In addition to the activities discussed above, implementation of a higher education planning model would require two steps: (1) linking the enrollment projection model developed as part of this applied research endeavor to existing and future models used for facilities planning and budgetary purposes; (2) testing and evaluating the usefulness of the prototype model at selected colleges or groups of colleges throughout the state thereby increasing the simulative ability of the model and making educational planners at the local level aware of its potential usefulness. In addition, this interaction will facilitate the establishment of an open communication channel between the planners at the state level and their counterparts at the separate institutions; a channel highly necessary in the development of a higher education information system for New York State.

B. Conclusions: Data Evaluation

In the case studies, data were collected in two ways; one involving unit sampling and the other, a combination of subjective estimates of knowledgeable people with preaggregated data found in other sources in the institution. However, it was necessary and will be necessary in any sampling procedure to make use of data from several sources both historical and subjective. It was found that the latter method required the least expenditure of time and money. In addition, this method appears very suitable for the analysis of small systems. In larger systems (i.e., those in which the number of components of the major classification scheme is large) it is worthwhile for a first approximation to be made on the basis of subjective estimates; in this way, form and content of the output can be viewed before a full scale data collection procedure is commenced. Subsequent analysis may show that the number of components in the major classification scheme is too large, or perhaps that the amount of data output is too great for facility of analysis.

In the case of unit record sampling (which is one method of obtaining input for a relatively large system), the conclusion may be drawn that the accuracy of the results will be a function of the sample size, sampling plan, and the actual raw data sources themselves. For large models, unit record sampling would provide much better results than the subjective estimates in terms of accuracy of the projections. However, the amount of information required increases as the square of the number of components in the major classification scheme, and, therefore, an optimal number of classifications exists beyond which the cost of sampling is greater than the worth of the data it would amass.

It was found highly expensive to initialize the model in its present form through unit record sampling; at Rensselaer the cost was over $1.05 per student. Unit record sampling, however, may be used for updating the historical information. This process will be made easier when computerized student records are available at institutions.

The case studies conducted as part of this project revealed that in those colleges studied, planners were starting construction of computerized information systems. It is recommended that work on the information system for the state be started now with the local level in order to develop consistent definitions, characteristics codes, and so forth, that will permit ready data retrieval from the colleges and universities.

C. Potential Utility of a Planning Model

The level of specificity and detailed knowledge required for the use of any computer model forces its user to formulate alternative plans in nearly operational terms. In addition, the particular model under consideration forces the planner to formulate his "what if" questions in equally specific terms, and thus helps assure that the contingency questions asked are meaningful.

The major areas of planning in the educational context which may be facilitated by a computerized planning model are those of facilities planning, faculty planning, curriculum planning, planning for contingencies, and general budgeting. In the sphere of facilities planning, a knowledge of the male-female ratio can give specific insights into the dormitory facilities required at some future date; by the same token, estimates of the number of married students are important in planning for married student housing; and a knowledge of intercollegiate flows and geographical origin of students can give insights into future new construction locations. Faculty planning is aided in that faculty required are a function of both the number of students by curriculum, and the student flows within a particular school. Use of the model would therefore contribute not only to a knowledge of the required numbers of faculty, but also the "mix" of their expertise.

The transition matrices, giving insights into the intercurricular movements of students, can aid in the comprehension of the electives "mix" desired by the students of different curricula. A knowledge of curriculum to curriculum flows would thus seem to give indications of the interests and background of students in a given curriculum, and curriculum planning may be more easily aligned with the desires of the students.

Finally, it may be concluded with regard to the potential utility of the model that the speed and computational power of the computer will be of great help in the evaluation of alternative plans, and the evaluation of the impacts of exogenous and endogenous variable changes. The capability of such evaluation has been explicitely provided in the model through the procedures associated with the input of "what-if?" questions.

Through construction of the prototype and collection of data in the case studies, it is implicit in this report that some data are more easily obtained than others. From development of desired information sets in each of the case studies, it is also apparent that some data are more important than others. In many cases an inverse relationship exists between importance and availability. It thus behooves the users of a fully implemented planning model patterned after the present prototype to determine exactly what information is desired as output of the model, and whether such information will be available as a result of development of a statewide information system for higher education. It must be stressed that development of an information system is not contingent upon a decision to develop a full scale planning model (although the reverse is true). The simulation must be viewed from the persepctive of statewide higher educational planning. From this vantage point, it becomes apparent that the model is merely another aid to the planner in his development of alternative courses of action. Furthermore, it cannot be used effectively unless it is recognized as a planning instrument rather than as a problem solver. The model might be likened to a highly sophisticated calculator which, if used continually, can be quite helpful in the evaluation of combinations of numbers, but which, if not understood, will generally lead to confusion, loss of time, and duplication of effort.

APPENDIX 4.A.1. Glossary of Variables and Parameters

4.A.2. Flowchart of the Computerized Prototype

A - corresponds to the word "yes" for comparison with input commands

AE - classified and categorized matrix of upper-level entrants

AMX - transition matrix

AMXSUM - transition matrix row-sums

AT - classified and categorized matrix of first-time freshmen

BAMX - regression coefficient matrix for transition matrices

BT - regression coefficient matrix for classified and categorized matrices of first-time freshmen

BE - regression coefficient matrix for classified and categorized matrices of upper-level entrants

DAMX - a core-storate area for smoothed and unsmoothed transition matrices from the year prior to the year in which changed projections are being introduced

E - vector of numbers of upper-level entrants by classification

II - number of components in the major classification scheme

II2 - an aggregating limit

IJ - may be used to denote the number of rows in V if this number is greater than the number of rows in AMX

IL - earliest year to be printed in any iteration - automatically set equal to the changed year

IL6 - year in which the aging process starts for all iterations subsequent to the first

IMAX - can be used to and program when changed year is that just prior to the "futuremost" year to be projected

IMZ - internal variable for determination of whether transfer of control should be made to the first-time freshmen aggregation and printout routines

INTYR - the year to be changed in absolute terms

INVX - a matrix containing the time-ordered matrices XPXIX

ISUB - a vector used for temporary storage of matrices to be printed, and elements to be changed in transition matrices and matrices of first-time freshmen and upper-level entrants

IWAY - determines the method of incorporation of changed values into subsequent projections

JJ - number of columns in a transition matrix

JJYR - contains the absolute value of the date for which data are to be printed

LDO - determines whether a projection or smoothing process is to be carried out

MM - upper limit on years to be projected or smoothed

N - lower limit on years to be projected

NCATI - number of categories in the first characteristic of the matrices of students

NOH - if an episodic update has been performed, the changed year values must be smoothed to their original values. NCH is set to 1 so that the changed year is included in the smoothing

NOBV - number of categories of characteristics

NPO - number of years of projections to be made in first iteration

NT - the zeroth year in absolute terms: subtraction of NT from any absolute year yields "year" in relative terms

NTYR - the input changed year in relative terms

NY - the earliest year upon which the projections are to be based

NYEARS - the number of years of historical data

NYEAR1 - the latest year upon which the projections are to be based

NYR - the first year for which historical data are available (in absolute terms)

NXVAR - the number of independent variables upon which the regression curve is to be based

PR - temporary internal file for storage of transition matrix percentages

R - permanent file of historical data

T - vectors of first-time freshmen by classification

TSUM1 -
TSUM2 - specified aggregations of T

V - matrices of total students by classification and category of characteristic

VALS - a vector of temporary storage of desired (input) changes to projected variables

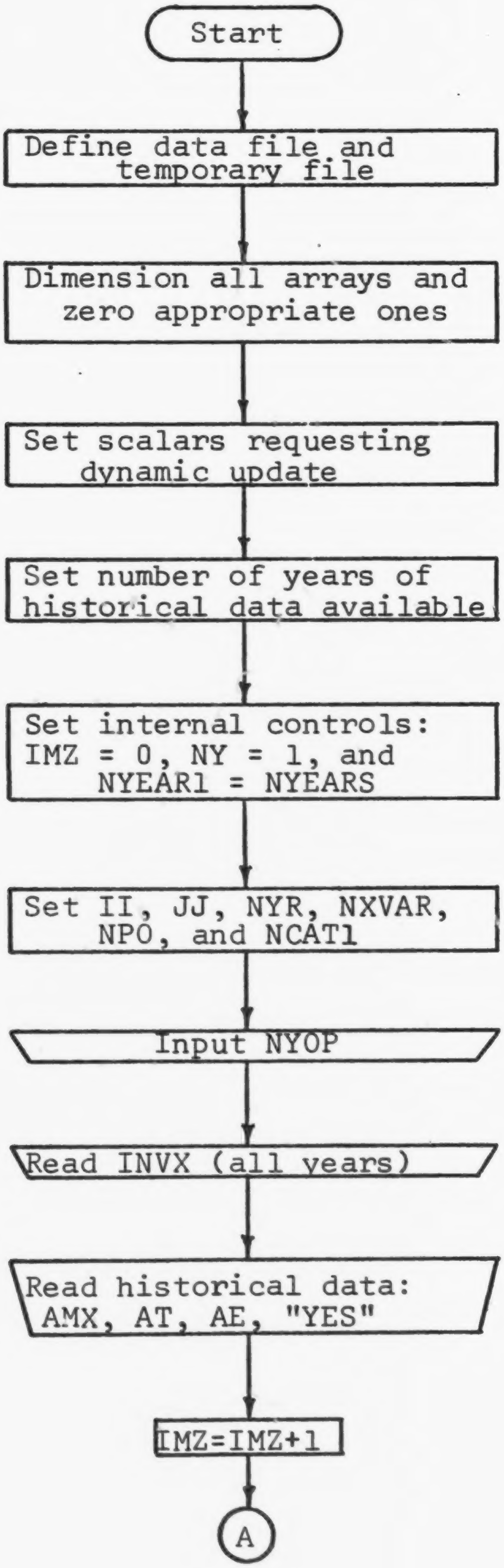
VSUM - vector of total students by classification

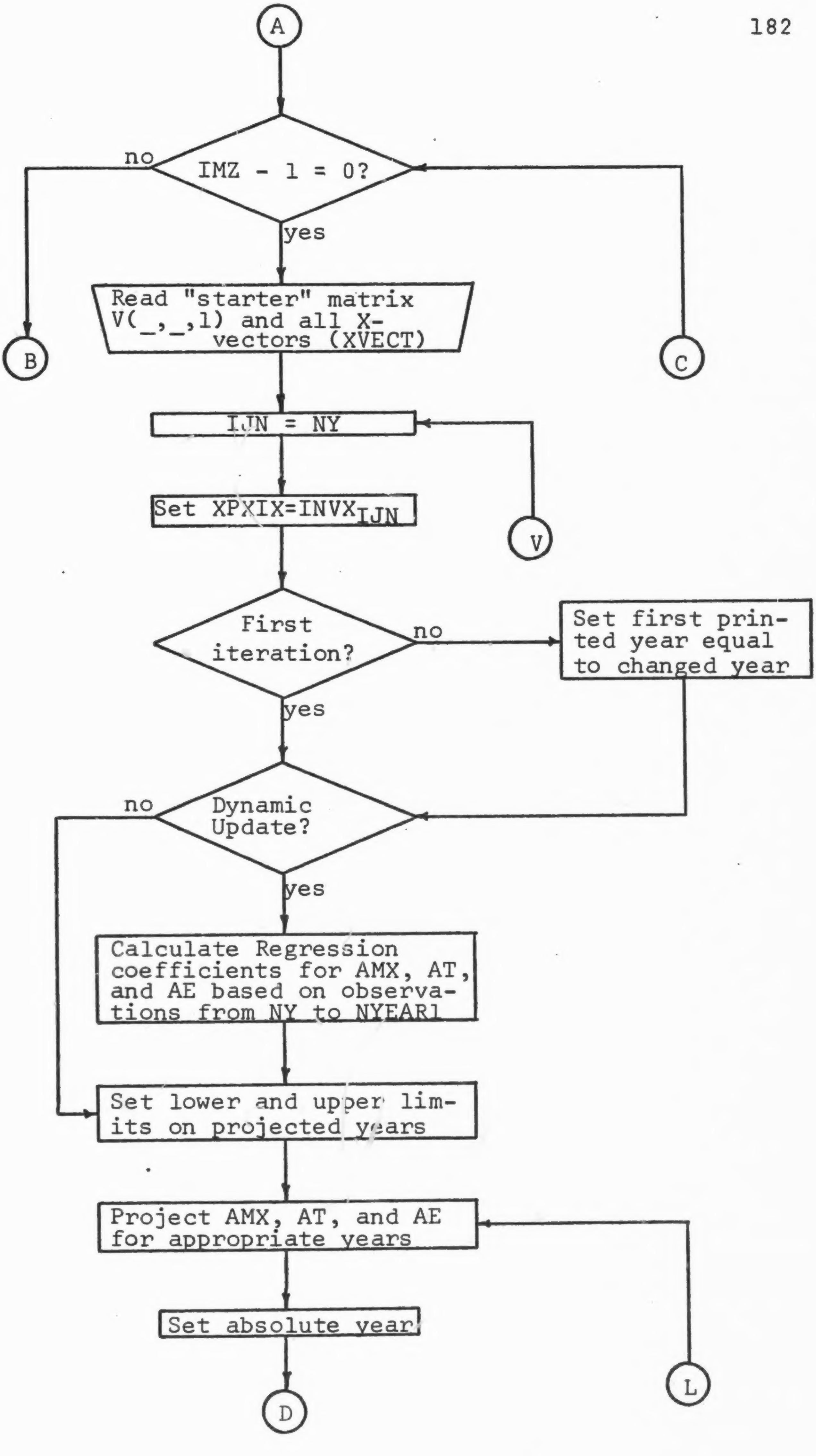
VSUM1 -
VSUM2 - specified aggregations of VSUM

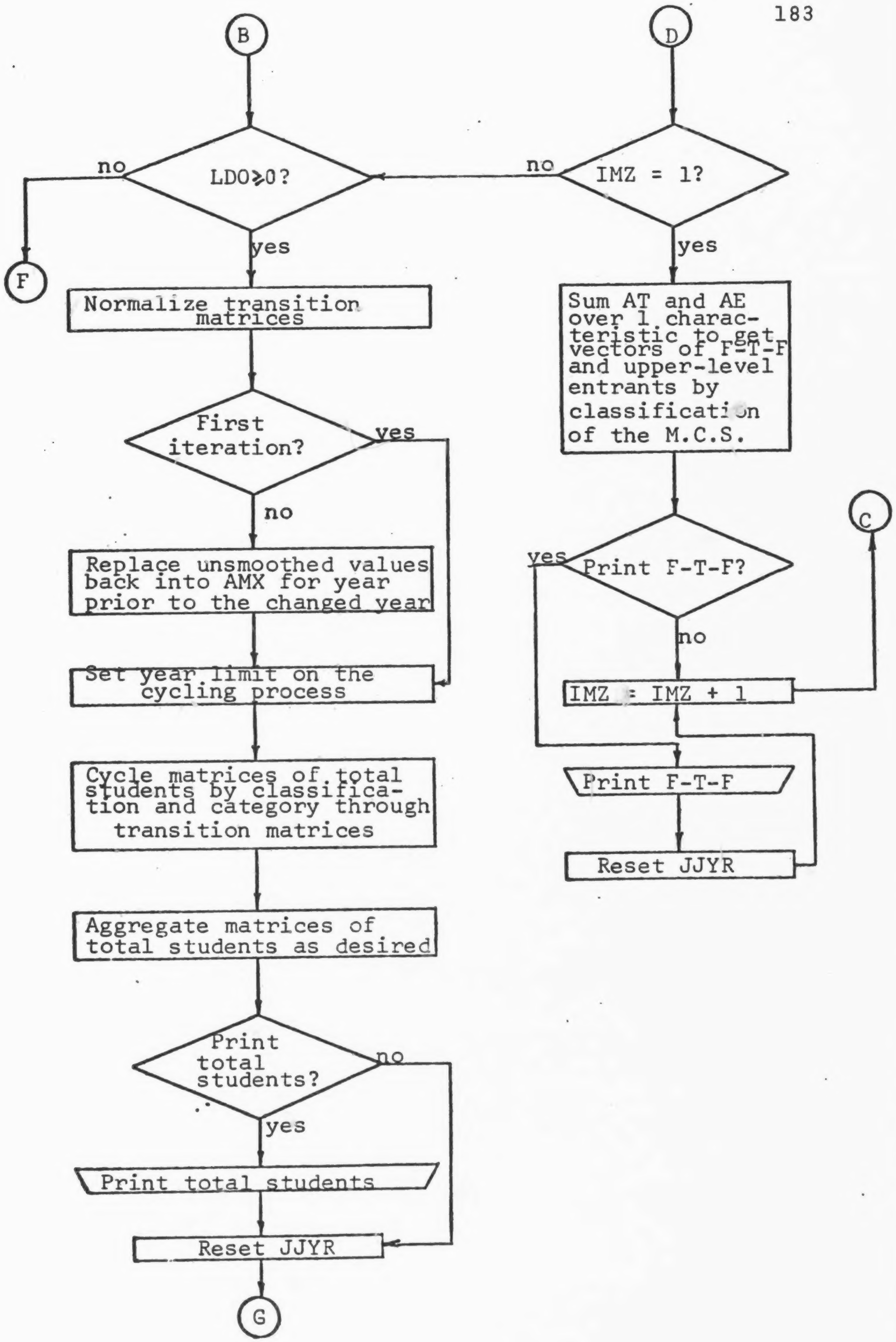
XPXIX - the matrix $(X'X)^{-1}X'$ for a particular set of projections

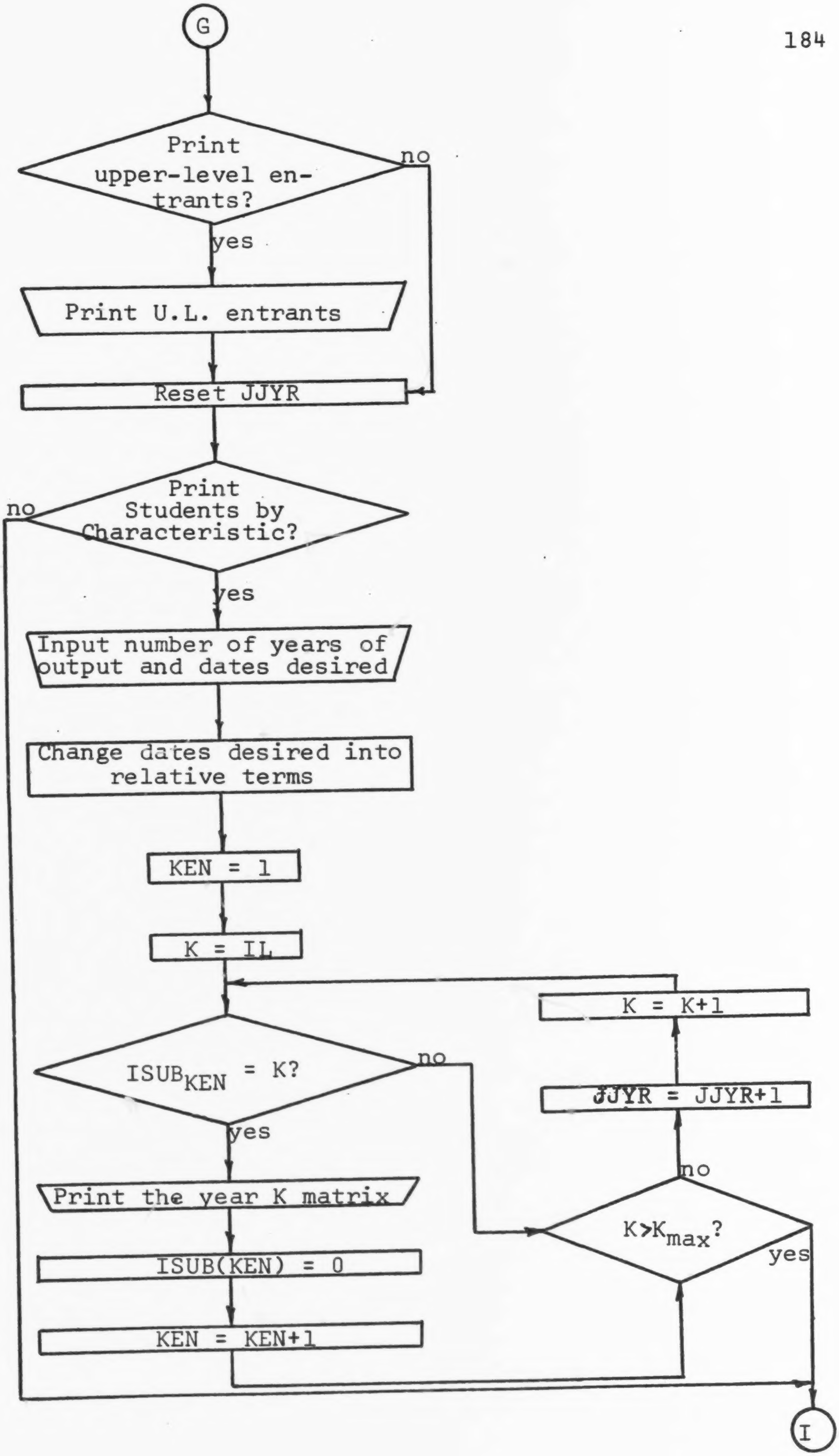
APPENDIX

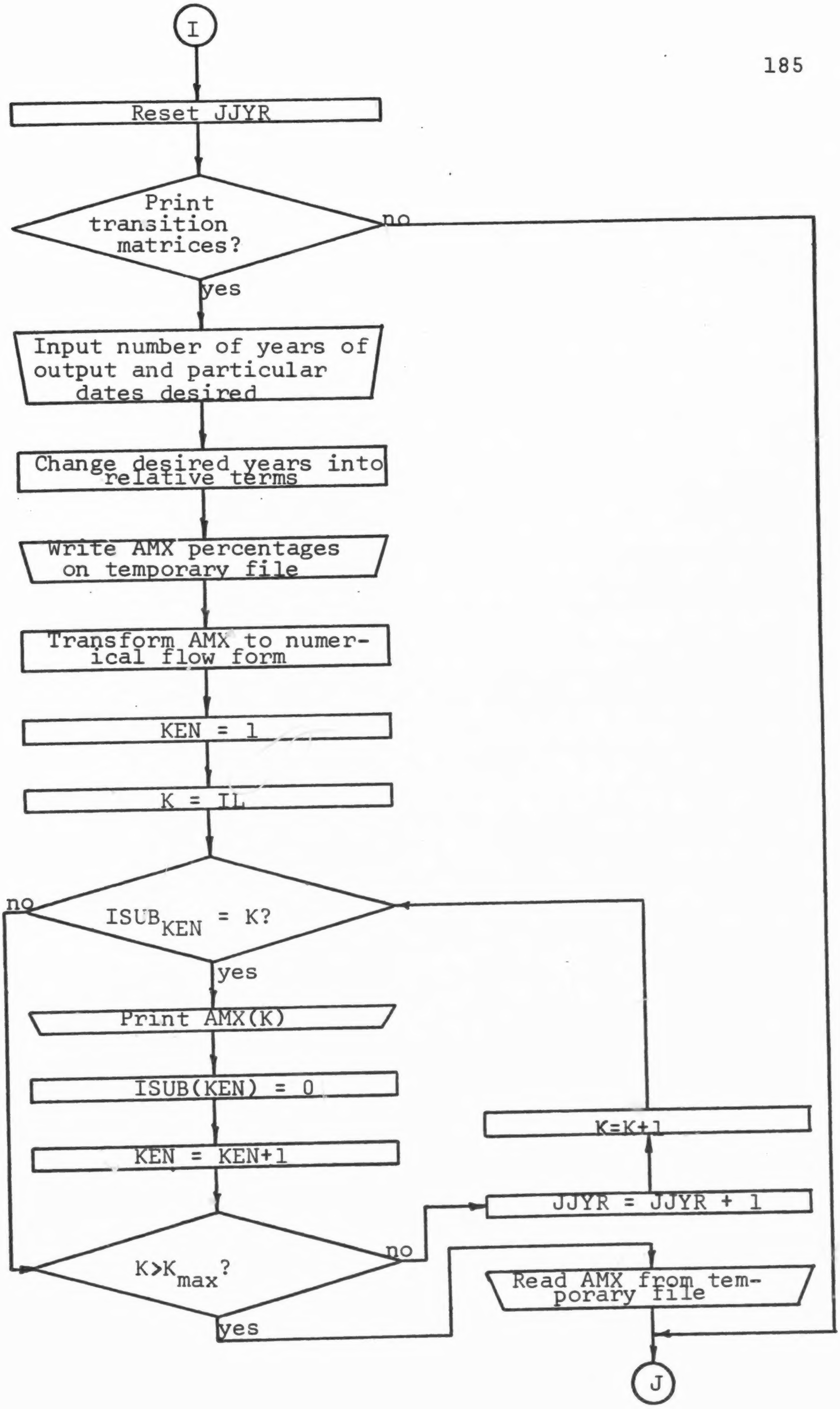
FLOWCHART OF THE COMPUTER MODEL

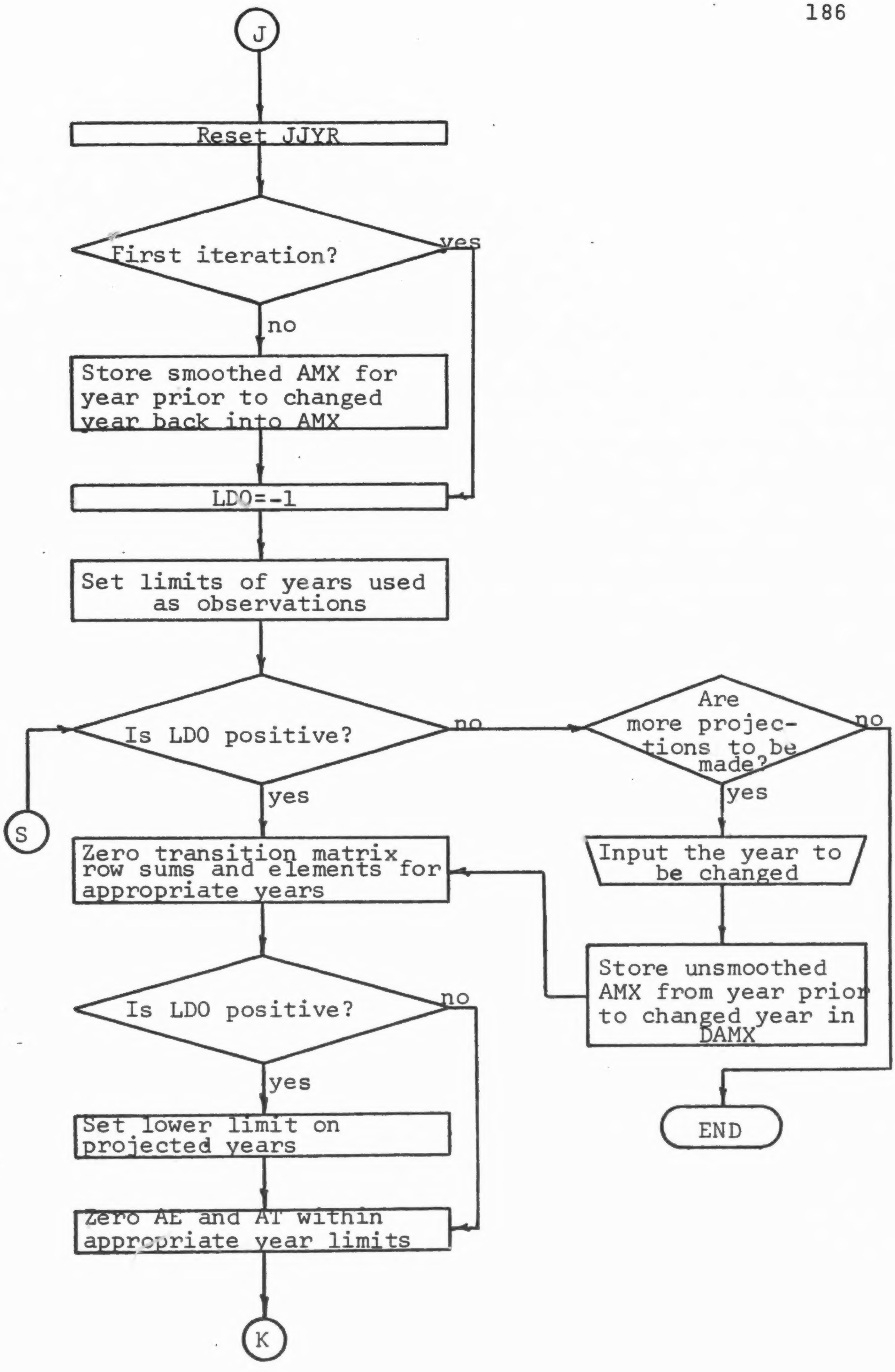

Start
Define data file and temporary file
Dimension all arrays and zero appropriate ones
Set scalars requesting dynamic update
Set number of years of historical data available
Set internal controls: IMZ = 0, NY = 1, and NYEAR1 = NYEARS
Set II, JJ, NYR, NXVAR, NPO, and NCAT1
Input NYOP
Read INVX (all years)
Read historical data: AMX, AT, AE, "YES"
IMZ=IMZ+1
A

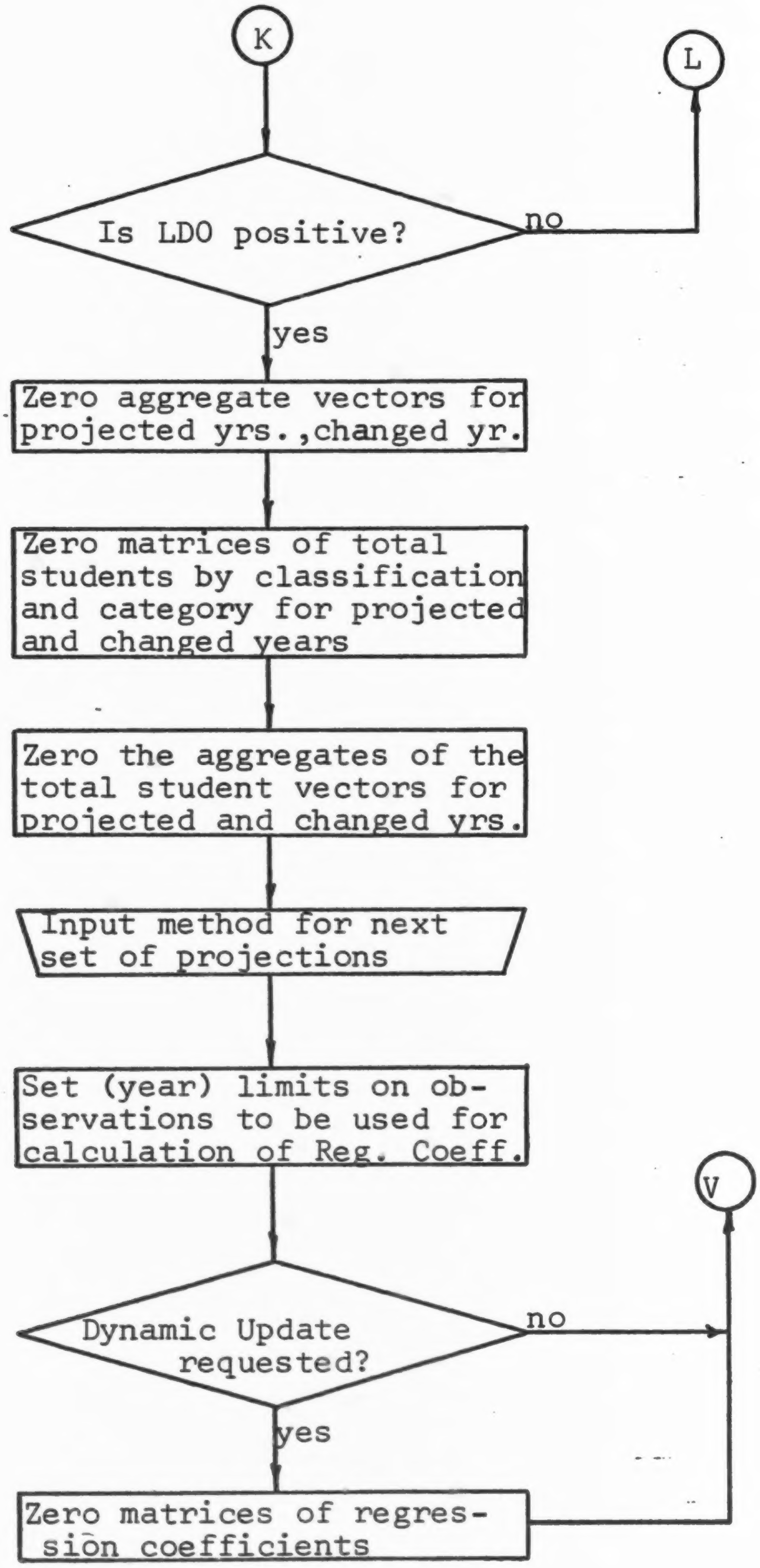

A
IMZ - 1 = 0?
no
yes
B
C
Read "starter" matrix V(_,_,1) and all X-vectors (XVECT)
IJN = NY
Set XPXIX=INVX$_{IJN}$
V
First iteration?
no
Set first printed year equal to changed year
yes
Dynamic Update?
no
yes
Calculate Regression coefficients for AMX, AT, and AE based on observations from NY to NYEAR1
Set lower and upper limits on projected years
Project AMX, AT, and AE for appropriate years
Set absolute year
L
D

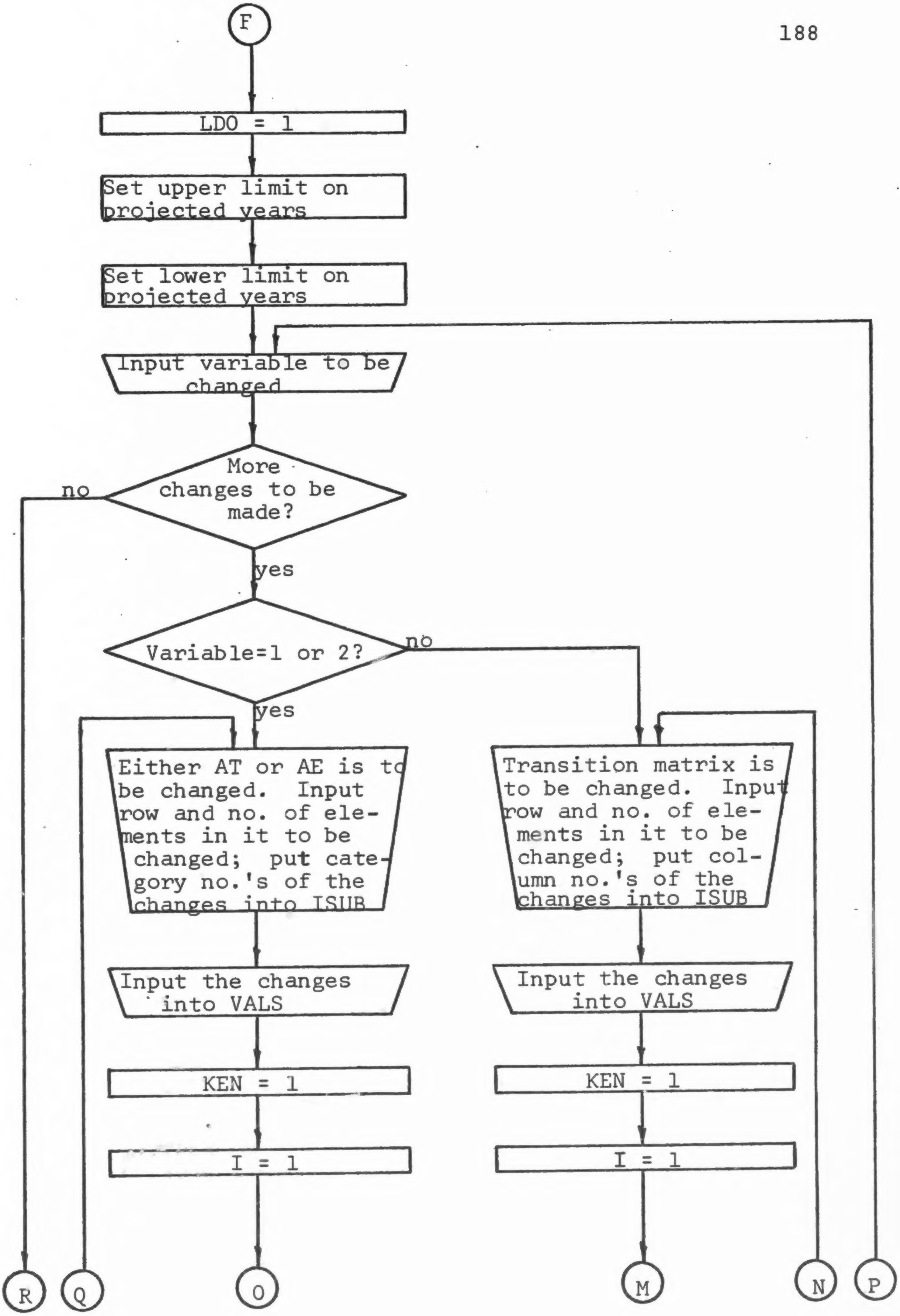

B
LDO≥0?
no
F
yes
Normalize transition matrices
First iteration?
yes
no
Replace unsmoothed values back into AMX for year prior to the changed year
Set year limit on the cycling process
Cycle matrices of total students by classification and category through transition matrices
Aggregate matrices of total students as desired
Print total students?
no
yes
Print total students
Reset JJYR
G
D
IMZ = 1?
no
yes
Sum AT and AE over 1 characteristic to get vectors of F-T-F and upper-level entrants by classification of the M.C.S.
C
Print F-T-F?
yes
no
IMZ = IMZ + 1
Print F-T-F
Reset JJYR

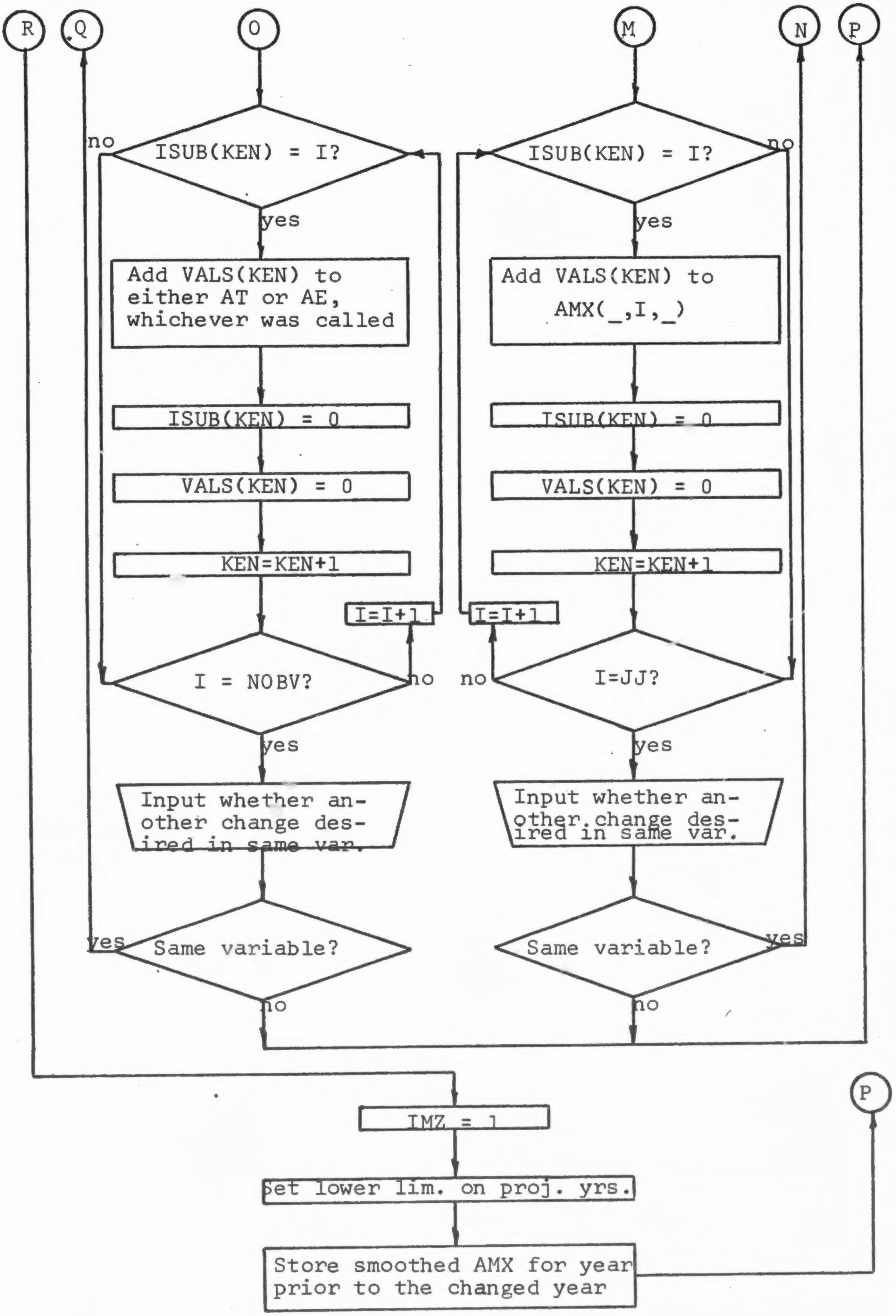

G
Print upper-level entrants?
no
yes
Print U.L. entrants
Reset JJYR
Print Students by Characteristic?
no
yes
Input number of years of output and dates desired
Change dates desired into relative terms
KEN = 1
K = IL
$ISUB_{KEN} = K$?
no
yes
Print the year K matrix
ISUB(KEN) = 0
KEN = KEN+1
K = K+1
JJYR = JJYR+1
no
$K > K_{max}$?
yes
I


I
Reset JJYR
Print transition matrices?
no
yes
Input number of years of output and particular dates desired
Change desired years into relative terms
Write AMX percentages on temporary file
Transform AMX to numerical flow form
KEN = 1
K = IL
no
ISUB$_{KEN}$ = K?
yes
Print AMX(K)
ISUB(KEN) = 0
KEN = KEN+1
K=K+1
JJYR = JJYR + 1
no
K>K$_{max}$?
yes
Read AMX from temporary file
J


J
Reset JJYR
First iteration?
yes
no
Store smoothed AMX for year prior to changed year back into AMX
LDO=-1
Set limits of years used as observations
Is LDO positive?
no
Are more projections to be made?
no
yes
S
yes
Zero transition matrix row sums and elements for appropriate years
Input the year to be changed
Store unsmoothed AMX from year prior to changed year in DAMX
Is LDO positive?
no
yes
END
Set lower limit on projected years
Zero AE and AT within appropriate year limits
K


K
L
Is LDO positive?
no
yes
Zero aggregate vectors for projected yrs.,changed yr.
Zero matrices of total students by classification and category for projected and changed years
Zero the aggregates of the total student vectors for projected and changed yrs.
Input method for next set of projections
Set (year) limits on observations to be used for calculation of Reg. Coeff.
V
Dynamic Update requested?
no
yes
Zero matrices of regression coefficients


F
LDO = 1
Set upper limit on projected years
Set lower limit on projected years
Input variable to be changed
More changes to be made?
no
yes
Variable=1 or 2?
no
yes
Either AT or AE is to be changed. Input row and no. of elements in it to be changed; put category no.'s of the changes into ISUB
Input the changes into VALS
KEN = 1
I = 1
Transition matrix is to be changed. Input row and no. of elements in it to be changed; put column no.'s of the changes into ISUB
Input the changes into VALS
KEN = 1
I = 1
R
Q
O
M
N
P


R
Q
O
M
N
P
ISUB(KEN) = I?
no
yes
Add VALS(KEN) to either AT or AE, whichever was called
ISUB(KEN) = 0
VALS(KEN) = 0
KEN=KEN+1
I=I+1
I = NOBV?
no
yes
Input whether another change desired in same var.
Same variable?
yes
no
ISUB(KEN) = I?
no
yes
Add VALS(KEN) to AMX(_,I,_)
ISUB(KEN) = 0
VALS(KEN) = 0
KEN=KEN+1
I=I+1
I=JJ?
no
yes
Input whether another change desired in same var.
Same variable?
yes
no
IMZ = 1
Set lower lim. on proj. yrs.
Store smoothed AMX for year prior to the changed year
P

APPENDIX 4.B

HUDSON VALLEY QUESTIONNAIRE

4

Data of Students Aging at Hudson Valley Community College

Please record below your subjective estimates in terms of percentages of students who begin a particular (freshman or senior) level in your division and develop over a time period of one academic year (from September to September). This process we call "aging". Students can age in three possible ways.

1) They can stay back and repeat that level in your division or stay back and transfer to another division at H.V.C.C. (in the same level).

2) They can leave the Hudson Valley Community altogether by one of two possible routes (transfer or withdraw and academic attrition).

3) They can advance from the freshman level to the senior level in your division or advance from the freshman level to the senior level and transfer to another division at Hudson Valley. A student can only graduate from the division in which he began his senior (or stay back senior) year.

We would appreciate this information for each of the five years from September 1963 through September 1967 during the students' matriculation at the College. Note that row totals should sum up to 100% at levels to where students have aged. If no students exist or begin a particular level for any one year, then the corresponding row should be left blank. If your estimates do not differ among the five years, then you need fill in only the first year (1963) to year (1964) aging process. Thank you for your cooperation.

Key:

I	Business Curricula Division
II	Engineering Technologies Division
III	Health Science Curricula Division
IV	Liberal Arts and General Studies Division
V	Physical Education, Health and Recreation Division
VI	Physical and Matural Sciences and Math Division

Fall 1964

Fall 1963	Students Age To													
	Freshman Level						Outside World by		Senior Level					
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	I	II	III	IV	V	VI
100% of Students Age From Freshman Level In Division I														

Fall 1964

Fall 1963	Students Age To								
	Senior Level						Outside World by		Completion of Degree Program
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	Division I
100% of Students Age From Senior Level In Division I									

Fall 1965

Fall 1964	Students Age To													
	Freshman Level						Outside World by		Senior Level					
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	I	II	III	IV	V	VI
100% of Students Age From Freshman Level In Division I														

Fall 1965

Fall 1964	Students Age To								
	Senior Level						Outside World by		Completion of Degree Program
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	Division I
100% of Students Age From Senior Level In Division I									

Fall 1966

Fall 1965 100% of Students Age From Freshman Level In Division I	Students Age To													
	Freshman Level						Outside World by		Senior Level					
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	I	II	III	IV	V	VI

Fall 1966

Fall 1965 100% of Students Age From Senior Level in Division I	Students Age To								
	Senior Level						Outside World by		Completion of Degree Program
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	Division I

Fall 1967

	Students Age To													
	Freshman Level						Outside World by		Senior Level					
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	I	II	III	IV	V	VI
Fall 1966 100% of Students Age From Freshman Level In Division I														

Fall 1967

	Students Age To								
	Senior Level						Outside World by		Completion of Degree Program
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	Division I
Fall 1966 100% of Students Age From Senior Level In Division I									

Fall 1968

Fall 1967	Students Age To													
	Freshman Level						Outside World by		Senior Level					
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	I	II	III	IV	V	VI
100% of Students Age From Freshman Level In Division I														

Fall 1968

Fall 1967	Students Age To								
	Senior Level						Outside World by		Completion of Degree Program
	I	II	III	IV	V	VI	Transfer or Withdrawal	Academic Attrition	Division I
100% of Students Age From Senior Level In Division I									

Please estimate the percent of male students in each level in your division for the beginning of the following academic years.

Fall	Freshman	Senior
1963		
1964		
1965		
1966		
1967		

Please estimate the percent of students in the senior level in your division which have transferred to H.V.C.C. from another school for the beginning of each of the following academic years.
Please estimate the percent of these transfers which are male.

Fall	Percent of Seniors which are Transfers	Percent of transfers which are male
1963		
1964		
1965		
1966		
1967		

FOOTNOTES

1. Rensselaer Research Corporation, *The Development of a Computer Model for Projecting Statewide College Enrollments: A Preliminary Study* (Prepared for the Office of Planning in Higher Education, State Education Department, University of the State of New York, January 7, 1968.

2. Zabrowski, E. K., Zinter, J. R., and Okada, T., *Student-Teacher Population Growth Model*, U. S. Department of Health, Education and Welfare, OE-10055, National Center for Educational Statistics, 1968.

3. Thonstad, T., "A Mathematical Model of the Norwiegan Educational System" *Mathematical Models in Educational Planning*, OECD, Paris, 1967, pp. 125-158.

4. Gani, J., "Formulae for Projecting Enrollments and Degrees Awarded in Universities," *Journal of the Royal Statistical Society*, Vol. 120, Part 3, 1963, pp. 400-409. (See also Chapter II of Bartholomew, D. J., *Stochastic Models for Social Processes*, John Wiley and Sons, 1967.

5. Koenig, H. E., Keeney, M. G., and Zemach, R., *A Systems Model for Management, Planning, and Resource Allocation in Institutions of Higher Education*, Division of Engineering Research, Michigan State University, September 30, 1968.

6. See the *Report of the Select Committee on the Future of Private and Independent Higher Education in New York State* (The Bundy Report). It's overriding purpose was to determine "how the state can help preserve the strength and vitality of our private and independent institutions of higher education, and yet at the same time keep them free."

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